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THE QUARTERLY JOURNAL OF
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Vol. XI 1959 Part 3

CHANGES IN THRESHOLD LEVEL PRODUCED BY A SIGNAL PRECEDING OR FOLLOWING THE THRESHOLD STIMULUS

BY

M. TREISMAN AND C. I. HOWARTH

From the Institute of Experimental Psychology, University of Oxford

In a previous experiment (Howarth and Treisman, 1958) it was shown that when a warning preceded a stimulus by a fixed interval, the threshold level for the stimulus was higher the longer the fixed interval. A model of this effect was proposed, assuming that the threshold criterion adopted by the subject at any moment was modified by his estimate of the probability of a stimulus at that moment.

Three predictions are derived and tested. It is found that: the standard deviation of the response is constant despite the shifts in threshold induced; the threshold continues to fall as the interval from warning to stimulus is decreased to zero, with the lowest threshold when the warning signal and the stimulus are simultaneous; and that a warning signal following the stimulus by an interval of less than 0·5 to 1 sec. also lowers the threshold.

INTRODUCTION

In investigating sensory thresholds a warning, or the regular sequence of the experiment, usually indicates to the subject when the stimulus is to be expected. In a recent paper (Howarth and Treisman, 1958) the effect of a warning on the threshold was investigated by varying the interval between a warning and the time of arrival of the stimulus, and it was shown that, when this interval varied between 1 and 9 sec., the threshold fell as the warning interval shortened. A hypothesis was proposed to explain these results, which, shortly, consisted in the following assumptions: the subject's decision can be adequately described as a signal-noise discrimination problem (cf. Tanner and Swets, 1954); the threshold is the criterion which the subject employs in making these discriminations. The criterion adopted will affect the probability of making false positive responses, which depends also on the probability of the stimulus occurring at any given moment. If some factor increases this probability, the criterion could then be lowered without increasing the number of false positive responses and, if this were done, the detection of threshold signals would be more efficient. It was suggested that when the subject knew that the stimulus, if presented, would come at the end of a fixed warning interval, he would alter his criterion—effectively lower his threshold—at the moment he expected the stimulus. Since estimation of a time interval is subject to a certain amount of error (which can be measured by the variability of repeated estimations of the time interval) there would appear to the subject to be a varying probability of the stimulus coming at the moments within a range of time about the estimated end of the interval, with the highest probability at this moment. Therefore the threshold would be lowered over a range of time at the end of the warning interval. Since the absolute variability

of the estimation of a time interval increases with the length of the time interval (Woodrow, 1930), this would mean that at longer intervals the threshold lowering would be distributed over a longer range of time and its maximal amount would be less, accounting for the smaller reduction in threshold produced as the warning interval was lengthened.

The present paper is an account of some further tests of this hypothesis. These took the form of testing the following predictions derivable from the hypothesis:—

(1) As the warning interval increases the standard deviation of the threshold judgements will decrease.

Since the threshold at the moment the stimulus comes will depend on the accuracy of each estimate of the warning interval, it will range between the normal threshold (when the estimate of the end of the warning period is completely out) and the maximally lowered theshold (when it is completely correct) and this maximal lowering will be greater the shorter the warning period. Therefore the range of the threshold judgements should be greater the shorter the interval. In the work cited above (Howarth and Treisman, 1958) this predicted result was found, but as the extent was not significant, it required confirmation.

(2) The exponential curve found should have a point of inflection at a short positive interval.

A threshold lowering process should have some latency, therefore, at warning intervals less than this latency, its efficiency would be reduced, and the threshold would rise again.

(3) There should be no effect when the warning coincides with or follows the stimulus, since at the moment of arrival of the stimulus the process cannot have been activated.

A description of the experiments will now be given, followed by a discussion of their implications.

Experimental Results

Experiment 1(a)

The aim of this experiment was to observe any significant relation between length of warning period and variability of response.

To ensure that any result found would not be peculiar to the psychophysical method previously used (constant successive decreases in stimulus intensity until the subject had given three successive negative responses—this will be referred to as "the descending method of limits"), the threshold was measured by two methods: the "descending method of limits" and the "method of constant stimuli" (i.e. two near threshold strengths of stimulus were alternated with "blanks" in a sequence determined from random number tables).

Method and apparatus. The apparatus has been described before (Howarth and Treisman, 1958). Briefly, it consisted of three electronic timers, employing Mullard Z803U valves. The subject, in a separate moderately illuminated room, sat 18 in. from a white cardboard screen, 20 in. by 24 in., at the centre of which were two neon bulbs. He wore headphones, which provided a constant 500 c.p.s. tone of about 60 to 70 db. SL. This tone came from a Muirhead audio-oscillator and passed through an amplifier. The sequence involved in administering a stimulus was as follows: the experimenter pressed a button which lit up the upper neon bulb, providing a prewarning, which was followed one second later by the warning bulb lighting up. This interval was determined by the first timer. The second timer determined the "warning interval," which was pre-set to be either 1, 3, or 9 sec. At the end of this interval the amplifier was switched in, to give a pre-set increase in the intensity of the tone, which was terminated, by the third timer.

The length and form of the pip were observed on a Cossor Oscillograph. Time intervals were recorded on a bank of Decatrons. The subject responded "Yes" or "No" to indicate whether he had heard the pip (which was about 30 millisec. in duration) or not.

The three thresholds were determined in order by the descending method of limits, and then again by the method of constant stimuli, with ten weak, ten strong and two blank stimuli being given for each interval. The two stimulus strengths, "weak," and "strong" were so chosen, on the basis of the first method of limits determination, as to lie near the subject's 50 per cent. response point. These six determinations were repeated four times in the course of a session, which lasted 1½ to 2 hr. The experiment consisted of nine sessions, four with one subject, five with the other. Two experienced subjects (the authors) were used. The order of testing thresholds was 1, 3, 9 in six sessions, and 9, 3, 1, in three. However, this order had no apparent effect on the results.

Each session began with one or two "warm-up" runs by the descending method of limits, which were discarded from the results.

Results

The method of limits. In each session, four estimates of the threshold were determined for each warning period, and the mean threshold, and its standard deviation, calculated. The average threshold, and the average standard deviation, for the nine sessions, were also calculated.

The method of constant stimuli. In each session, for each warning interval, the proportions of the 40 "weak" and the 40 "strong" stimuli heard were converted into probits, and the slope of the line through these two points was calculated. The stimulus strength corresponding to a 50 per cent. response was calculated and taken as the threshold. The average threshold, and average slope, for the nine sessions was calculated and the average standard deviation of response estimated from the latter, using the formula $\sigma = \frac{1}{b}$, where b is the probit regression coefficient (Finney, 1952).

See Table I.

TABLE I

Warning intervals	1 sec.	3 sec.	9 sec.
Method of limits			
Average threshold (db.)	0·58	0·68	0·73
Average S.D.	0·069	0·077	0·081
Method of constant stimuli			
Average threshold (db.)	0·45	0·62	0·66
Average S.D.	0·164	0·168	0·128
False positives (percentages)	1·4	2·8	4·2

To determine the significance of these results, analyses of variance were performed on the standard deviations and the probit regression coefficients, for the 9 sessions.

The analyses of variance showed that the changes in the standard deviation with different sessions and warning intervals were not significant even at the 20 per cent. level.

Each false positive rate is based on 72 stimuli.

Experiment 1(b)

Although the results in the experiment above were not significant, the S.D. as determined by the method of constant stimuli appeared to be constant or rise from 1 to 3 sec., and then to fall at 9 sec. This effect might have become significant with more data, and the following experiment was performed to check this.

Apparatus and method. The apparatus was as in the previous experiment. Only two warning intervals, and the method of constant stimuli, were used. Four stimulus strengths, spaced 0·10 db. apart, were used for each warning interval. A run consisted of four stimuli at each strength, and four blanks, ordered by reference to random number tables. A session consisted of ten alternating runs, five with one warning interval, five with the other. The stimulus was a 50 millisec. pip superimposed on the 500 c.p.s. tone.

In the first part of the experiment (i) the prewarning was 2 sec. and the warning intervals were 1 and 8 sec. Four subjects each gave three sessions. In the second part (ii) two subjects each did two sessions, with the prewarning 1 sec. and the warning intervals 3 and 6 sec.

Results

The sessions for each subject were combined and probit analysis (Finney, 1952) and analysis of χ^2 performed to see whether there was any significant departure from parallelism of the probit regression lines for the individual subjects, and for the experiment as a whole.

The results of the analysis of χ^2 for each subject, and each part of the experiment as a whole, and the thresholds determined for each warning interval and subject are given in Table II.

TABLE II

Subject	χ^2 *for parallelism*	*d.f.*	*Significance*	*Threshold (db.) & S.E.*		*S.D.* $\left(\sigma = \frac{1}{b}\right)$
				1 *sec.*	8 *sec.*	
Experiment (i)						
C.I.H.	0·006	1	$P > 0·1$	0·39 ± 0·013	0·55 ± 0·012	0·135
M.T.	0·370	1	$P > 0·1$	0·51 ± 0·012	0·55 ± 0·012	0·119
J.H.	3·154	1	$0·1 > P > 0·05$	0·42 ± 0·008	0·46 ± 0·009	0·075
V.S.	5·693	1	$0·02 > P > 0·01$	0·41 ± 0·013	0·55 ± 0·013	0·125
Combined results	0·605	1	$P > 0·1$	0·43 ± 0·006	0·51 ± 0·006	0·114
False positives (per cent.) ..				2·5	4·2	
Experiment (ii)				3 *sec.*	6 *sec.*	
C.I.H.	0·535	1	$P > 0·1$	0·42 ± 0·032	0·47 ± 0·025	0·199
M.T.	0·792	1	$P > 0·1$	0·55 ± 0·014	0·58 ± 0·015	0·117
Combined results	0·026	1	$P > 0·1$	0·53 ± 0·013	0·55 ± 0·013	0·157
False positives (per cent.) ..				2·5	2·5	

t-tests of combined results (taking $n = \infty$) *(Thresholds)*
Experiment (i) $t = 10·39$ $0·001 > P$.
Experiment (ii) $t = 1·39$ $0·2 > P > 0·1$.

χ^2 for heterogeneity is not reported as in no case was it significant.

Only one subject showed any significant departure from constancy of the standard deviation. The experiment as a whole shows no significant change in the standard deviation.

The standard deviations of the response distributions are the reciprocals of the probit regression coefficients. The standard errors, given with each threshold, indicate the reliability of the threshold determined from the responses by probit analysis.

Each false positive rate is based on 240 stimuli in part (i), and on 80 stimuli in part (ii).

Experiment 2(a)

The aim of this experiment was to determine the shape of the curve between 0 and 1·5 sec., and, more specifically, to determine whether there was a point of inflection.

Apparatus. This was similar to that already described. The constant 500 c.p.s. tone at 60 to 70 db. S.L. was used, with a 50 millisec. intensity increment as the stimulus.

Method. Eight subjects were used, each for two sessions. To control for possible effects of prewarning, two prewarning intervals were used: half the subjects had an 8 sec. prewarning at their first session, and a 1 sec. prewarning at their second session, and half the reverse.

Thresholds were determined by the descending method of limits at the warning intervals and in the order 0, 0·3 sec., 0·6 sec., 0·9 sec., 1·5 sec. Such a series was repeated four times in a session. Mean thresholds and standard errors were computed as described before (Howarth and Treisman, 1958), and an analysis of variance performed on the individual thresholds, the factors examined being the effects of Subjects, Prewarnings and Warning Intervals. Examination of the results did not show any systematic effect of the order in which the two prewarnings were given. Subjects responded verbally, and were in telephonic communication with the experimenter.

Results

See Table III.

These results do not show a point of inflection in the curve, which appears to continue down to zero. However, this does not completely exclude the possibility of a point of inflection lying between 0 and 300 millisec., the curve dipping and then rising as the warning approaches zero, to reach a level similar to that at 300 millisec. This point is tested in Experiment 2(*b*).

TABLE III

COMBINED RESULTS FOR 8 SUBJECTS IN 16 SESSIONS: MEANS AND STANDARD ERRORS (DB.)

Intervals (sec.) ..	0·0	0·3	0·6	0·9	1·5
Prewarning					
1 sec. ..	0·54 ± 0·025	0·59 ± 0·013	0·66 ± 0·015	0·67 ± 0·025	0·71 ± 0·016
8 sec. ..	0·62 ± 0·016	0·63 ± 0·021	0·64 ± 0·024	0·66 ± 0·018	0·71 ± 0·023
Combined	0·58 ± 0·015	0·61 ± 0·013	0·65 ± 0·014	0·66 ± 0·015	0·71 ± 0·014

Analysis of Variance

Factors	*d.f.*	*Variance ratio*	*Significance*
Subjects	7	22·26	0·001 > P*
Warnings	4	9·04	0·001 > P*
Prewarnings	1	3·02	0·1 > P > 0·05
S × W	28	1·40	0·2 > P > 0·1
W × P-W	4	1·03	P > 0·2
S × P-W	7	6·73	0·001 > P*
Residual	28		

The analysis of variance confirms the presence of variability of behaviour between different subjects, and the significance of warning interval. The effect of prewarning alone is not significant, but the interaction between prewarning and subject is significant. Though the thresholds for the two prewarnings are very similar at the longer warning intervals, they are lower with the 1 sec. prewarning, at the 0·0 and 0·3 sec. warning intervals, than with the 8 sec. prewarning. A *t*-test between the threshold values at 0·0 sec. for the two prewarnings gives: $t = 1{\cdot}8084$; $0{\cdot}1 > P > 0{\cdot}05$.

Thus there is a suggestion, though it is not significant, of greater lowering at the shortest intervals when the prewarning is short. One explanation which would account for this, and for the failure to find a point of inflection, is that the curve may be partly artefactual, due to the prewarnings acting as warnings and thus obscuring an inflection, and giving a steep curve when the time from prewarning to stimulus ranges between 1 and 2·5 sec., and a flatter curve when it ranges between 8 and 9·5 sec. Differences in the use made of the prewarning in this way by different subjects would account for the significant Subject × Prewarning interaction. This point is tested in Experiment 2(*c*).

Experiment 2(b)

This experiment examined warning periods between 0·05 and 0·30 sec.

Method and apparatus were as for Experiment 2(*a*) save that the warning intervals used were 0·05, 0·10, 0·15, 0·20 and 0·30 sec. The prewarning was 1 sec. in all cases. Four subjects gave two sessions each. In one session for each subject the thresholds were taken four times in the order given above, in the other in the reverse order.

Results

Since the results for the two orders of administration were not significantly different, they were combined, and are given in Table IV.

No evidence of a point of inflection is found.

TABLE IV

THRESHOLDS: MEAN AND STANDARD ERROR OF MEAN (DB.)

Intervals (sec.) ..	0·05	0·10	0·15	0·20	0·30
Threshold	0·41 ± 0·024	0·48 ± 0·021	0·50 ± 0·021	0·51 ± 0·017	0·52 ± 0·024

Experiment 2(c)

In a previous experiment (Howarth and Treisman, 1958) it was found that warning periods of different lengths given in a randomized order unknown to the subject had little or no distinctively different effect. Therefore, in the following experiment, the possibility that the prewarning had served as a subsidiary warning was controlled by making the prewarning randomly variable over a large range.

Method and apparatus. The randomizing apparatus described before (Howarth and Treisman, 1958) was used to give a prewarning randomly variable between 2 and 7 sec.

The experiment was identical in design with Experiment 1(*b*) save that the prewarning was variable, and that the two warning conditions were: (i) No warning given, and (ii) simultaneous warning—i.e. zero warning interval. Two subjects each did three sessions.

The four stimulus strengths used were: 0·22, 0·33, 0·44 and 0·55 db. The pip was 45 millisec. long.

Results

A probit analysis, and an analysis of χ^2 were performed on the combined results of the six sessions. The results are given in Table V.

Each false positive rate is based on 120 stimuli.

The fall in threshold produced by the zero warning interval is confirmed. The constancy of the standard deviation provides further confirmation of Experiment 1.

TABLE V

Interval	*Simultaneous warning*	*No warning*
Threshold and S.E. (db.)	0·36 ± 0·008	0·46 ± 0·009
False positives (per cent.)	6·7	8·3
Standard deviation of response $= \left(\sigma = \frac{1}{b}\right)$	0·104	0·104

Analysis of χ^2	*d.f.*	χ^2	*Significance*
Parrallelism of regressions	1	0·0032	$P > 0·9$
Residual heterogeneity	4	0·8941	$P > 0·9$
Total	5	0·8973	$P > 0·9$

Experiment 3(*a*)

In this experiment an attempt was made to determine the effect of a warning following the stimulus (a "negative warning") and to compare it with the threshold curve obtained when the warning preceded the stimulus.

Apparatus and method. The same apparatus was used. Two subjects each did four sessions. Each session consisted of four series of threshold measurements by the descending method of limits. The first neon gave the prewarning, which was followed at a constant 5 sec. interval by the second neon, giving the warning. The stimulus preceded or followed the warning. In the "No warning" condition the stimulus came 5 sec. after the first neon, and the second neon did not go on. In two of each subject's sessions the order was: No warning, −1·5 sec. (i.e. the stimulus—a 50 millisec. pip—preceded the warning by 1·5 sec.), −0·5 sec., 0, 0·5 sec. and 1·5 sec.; and in the other two sessions the order was the reverse.

Results

See Figure 1, curve A, and Table VI.

TABLE VI

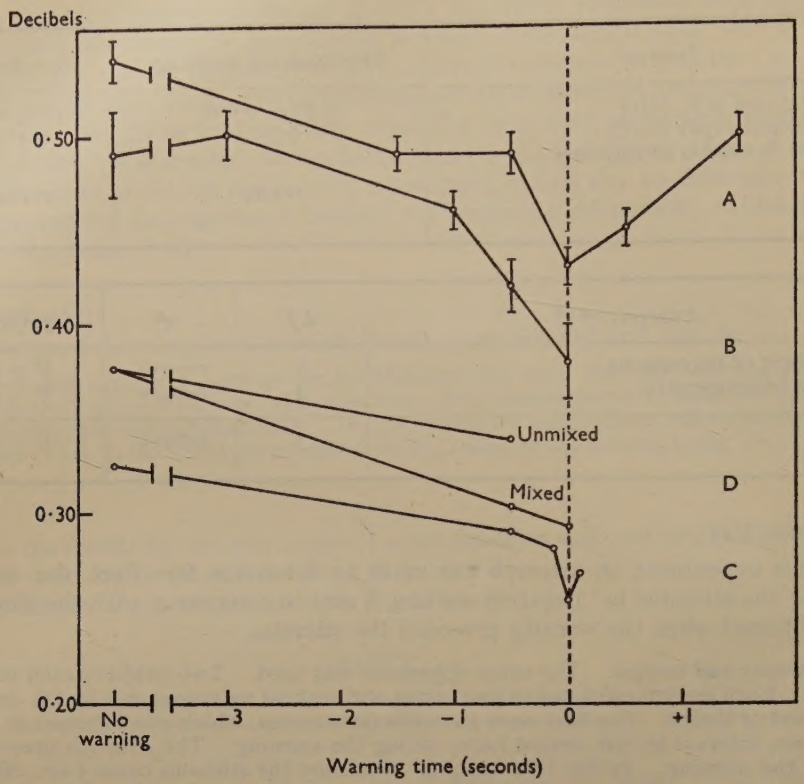
Interval	*No warning*	−1·5	−0·5	0·0	0·5	1·5
Threshold and S.E. (db.) ..	0·54 ± 0·011	0·49 ± 0·008	0·49 ± 0·010	0·43 ± 0·010	0·45 ± 0·010	0·50 ± 0·010

Although this result appears to indicate a fall in threshold with "negative warnings," as compared with the "No warning" condition, there is a possibility that this may be artefactual, due to a direct "positive warning" effect of the prewarning. Further experiments are necessary to exclude this.

Experiment 3(b)

In this experiment the prewarning varied randomly between 2 and 7 sec., when it was followed by the stimulus, which in turn was followed by the warning.

FIGURE 1



Curve A gives the results of Experiment 3(*a*), curve B of 3(*b*), curve C of 3(*c*) and curve D of 3(*d*). Warning period in seconds is given on the abscissa and threshold level in decibels on the ordinate. Standard errors are shown in curves A and B. For curve A thresholds were measured by the descending method of limits, with a fixed 5 sec. interval between prewarning and warning. For curve B the method of limits was again employed but the interval between prewarning and stimulus varied randomly between 2 and 7 sec.

Curve C: thresholds were obtained by the method of constant stimuli. Mean differences between adjacent pairs of thresholds were calculated and added to the mean threshold value at −0·1 sec. to give the curve. The significance of these differences are given in Table VIII. Curve D is similarly derived, differences between the "No warning" thresholds and the −0·1 and −0·5 thresholds in "mixed" and "unmixed" series being subtracted from the mean threshold value of the "No warning" condition in the three series (see Table IX).

Method. Two subjects each gave two sessions. The thresholds were recorded by the descending method of limits, in the order: No warning, −3 sec., −1 sec., −0·5 sec., 0, in two sessions, and in the reverse order in the other two.

Results

See Figure 1, curve B, and Table VII.

A negative warning effect is shown despite the randomized prewarning intervals.

Experiment 3(c)

In this experiment reaction times for the responses were recorded. If at, say, the −0·5 sec. warning interval, the threshold was lowered as compared with the "No warning" condition, this might be because a certain number of stimuli which, under

the "No warning" condition, might have evoked a negative response with little delay, would now give a delay and, after the warning came, a positive response. In this case the average RT (reaction time) for positive responses would be increased by the addition of a number of reaction times exceeding 0·5 sec.

TABLE VII

Interval ..	No warning	−3·0	−1·0	−0·5	0·0
Threshold and S.E.	0·49 ± 0·023	0·50 ± 0·013	0·46 ± 0·010	0·42 ± 0·013	0·38 ± 0·019

Method and apparatus. The subjects responded by depressing one of two reaction keys. That on the right signalled "Yes" and that on the left "No." The time from the prewarning to the stimulus or warning (whichever came first) was randomized between 2 and 7 sec. and was recorded on the Decatrons, which also recorded the RT from the stimulus to the subject's response. The method of constant stimuli was used, a series for a given warning period consisting of four stimuli at each of four stimulus strengths equally spaced on a db. scale, and four blanks, randomly ordered. Five warning periods were used: "No warning", −0·5, −0·1, 0 and +0·1 sec., three being used in any one session, these being "No warning," −0·5 and −0·1, or −0·1, 0 and +0·1, in those or the reverse orders. Three series repeated five times took two sessions to complete, and four subjects each gave 8 sessions. A 43 millisec. stimulus was used.

TABLE VIII

16 Sessions

Mean threshold differences (db.)		*S.E.*	*t*	*Significance*
"No warning"—(−0·5)	0·034	±0·010	3·40	0·001 > P
(−0·5) − (−0·1)	0·009	±0·010	0·90	P > 0·3

	No warning	−0·5	−0·1
Mean RT (sec.)			
(positive responses)	0·91	0·86	0·82
(negative responses)	—	1·39	1·08
False positives (per cent.)	10·0	6·3	8·1

16 Sessions

Mean threshold differences (db.)		*S.E.*	*t*	*Significance*
(−0·1) − 0..	0·027	±0·010	2·70	0·01 > P
0 − (+ 0·1)	−0·014	±0·011	1·27	P > 0·2

	−0·1 *warning*	0	+0·1
Mean RT (sec.)			
(positive responses)	0·89	0·83	0·76
(negative responses)	1·13	1·03	1·04
False positives (per cent.)	8·8	7·5	11·9

Results

Probit analyses were performed to determine the threshold and its variance for each warning period for each subject. The difference between each successive pair of thresholds, and its variance, was then calculated. For each pair of successive thresholds the mean weighted difference for all the subjects and its variance, were calculated (weights being the reciprocals of the variances). A similar series of comparisons was made for the probit regression (slope) coefficients, but as none of these differences were significant, they are not reported. The mean threshold at the −0·1 sec. warning period was calculated, since there were twice as many readings available for this point as for the others, and the differences added to or subtracted from it to give curve C in Figure 1. See Table VIII (Finney, 1952).

The threshold lowering with the negative warning is shown again. The threshold at −0·5 is significantly lower than with no warning. The threshold at −0·1 is lower than at −0·5 though the difference is not significant. The threshold at 0 is significantly lower than at −0·1, and lower, though the difference is not significant, than at +0·1. That the lowering of the threshold is not due to guessing is indicated by the fact that the false alarm rate tends to be lower when the threshold is low, rather than the reverse.

Each false positive rate is based on 160 blank stimuli, and the RT's are based on a total of 2,139 positive and 1,354 negative reactions. 11 RT's in the "No warning" condition which were presumed to be due to false positives (they all exceeded 3 sec. in length) were excluded from the calculation.

The reaction time for positive responses increases as the negative warning interval increases in length, as would be expected. The longest average reaction time is for the "No warning" condition. This may be partly due to not excluding all long reaction times due to false positives from this series, or to a difference of "set" between those conditions where a warning was expected and this one. The first explanation is supported by Figure 2A, in which positive reaction times greater than 1·7 sec. are not recorded (these occurred mainly in the "No warning" condition). The figure shows that if they were excluded the mean RT in the "No warning" condition would be a little less than with the −0·5 sec. warning period for two subjects.

In Figure 2A the reaction times for positive responses, for two of the four subjects, in the −0·5 and "No warning" conditions, are shown. Measuring the reaction times to the nearest tenth of a second, the total number of reactions of each duration up to 1·7 sec. under the "No warning" condition is shown. For each duration the difference between the number of positive reactions of that duration given under the −0·5 condition, and the number under the "No warning" condition, is also shown. The sum of the two distributions would be the distribution of all positive reactions under the −0·5 condition. It can be seen that there is an increase in the total of positive responses under the latter condition, and that the mean of the distribution of the excess is greater than 0·5 sec., and greater than the mean for all the positive responses at −0·5 sec. Reaction times of less than 0·5 sec. are decreased in the −0·5 condition as compared with the "No warning" condition, suggesting a tendency to delay positive responses when a warning was expected. The difference is significant at less than the 0·01 level using the one-tailed binomial test (Siegel, 1956).

Reaction times for the negative responses are uniformly longer than for positive responses, even in the +0·1 condition.

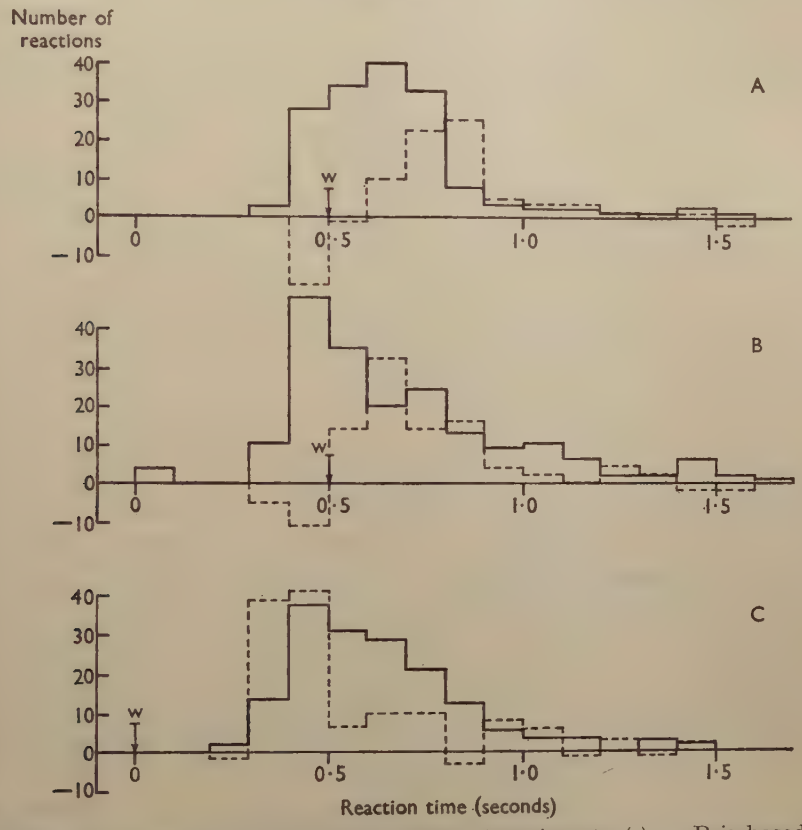
However, it could be argued in explanation of these results that in the series with the "negative warning" interval there might have been an "increase in effort" or other change in set, capable of lowering the threshold, but not representing a direct

effect of the warning on the decision when a doubtful response is delayed. To meet this argument Experiment 3(*d*) was performed.

Experiment 3(d)

This experiment was intended to exclude a general set of any sort as the factor determining the threshold level for a series of stimuli under a given warning condition. This was achieved by randomly alternating in each series a "negative warning,"

FIGURE 2



2A is based on two of the four subjects from Experiment 3(*c*). 2B is based on mixed series A ("No warning" and "−0·5") and 2C on mixed series B ("No warning" and "o") of Experiment 3(*d*). In each figure the continuous line shows the number of reaction times of each duration occurring under the "No warning" condition (positive responses only are considered). In 2A and 2B this distribution has been subtracted from the corresponding distribution of the positive responses in the −0·5 condition, and the difference is plotted as a dotted line. In 2C the "No warning" positive responses have been subtracted from the "o" responses and the difference plotted in the same way.

i.e. a warning following the stimulus, and the "No warning" condition. The "set" at the time of arrival of the stimulus would then be uniform whether or not there was a subsequent warning. If the reductions in threshold found earlier were solely due to differences of "set" they should disappear in this experiment. If differences in "set" between series were present, but not responsible for the threshold differences, they should affect both thresholds measured in a given series in the same way.

However, even if the differences previously found between the two thresholds measured in a series—e.g. under the −0·5 sec. and "No warning" conditions—had been caused by a "set" they might be fallaciously reproduced in this experiment if mixing two conditions induced a "set" to delay "Yes" responses and change them to "No" if no subsequent warning occurred, which would raise the "No warning" threshold. To control for this possibility, measurements of thresholds under the "unmixed" condition, as in Experiment 3(*c*), were also made in some of the sessions. Since significant changes in false positive rates might result from changes in the tendency to guess in different conditions, these too, were recorded.

TABLE IX

	Mean threshold differences (db.)	*S.E.*	*t*	*Significance*
WITHIN SERIES				
Mixed series A: No warning and −0·5 "No warning"—"−0·5"	0·072	±0·016	4·50	0·001 > P
Mixed series B: No warning and 0 "No warning"—"0"	0·085	±0·018	4·72	0·001 > P
Unmixed series "No warning"—"−0·5"	0·038	±0·014	2·71	0·01 > P
BETWEEN SERIES				
No warning (Mixed series A) —No warning (Mixed series B) ..	0·017	±0·019	0·89	P > 0·3
No warning (A)—No warning (unmixed)	−0·005	±0·016	0·31	P > 0·7
No warning (unmixed)—No warning (B)	−0·008	±0·028	0·29	P > 0·7
"0·05" (A)—"0·5" (unmixed)	−0·032	±0·21	1·52	P > 0·1
"−0·5" (A)—0	−0·008	±0·016	0·50	P > 0·6

	Mixed series (10 *sessions*)				*Unmixed series* (6 *sessions*)	
	A		*B*			
	No warning	−0·5	*No warning*	0	*No warning*	−0·5
Mean reaction times (sec.) (positive responses only) ..	0·74	0·70	0·63	0·62	0·63	0·67
False positives (per cent.) ..	4·5 (200)	4·0 (200)	4·5 (200)	7·0 (200)	0·0 (40)	2·4 (41)

Method. Three subjects did ten sessions, two doing four each and one doing two. A session consisted of ten series of stimuli, each series containing twenty stimuli: four blanks and two at each of three stimulus strengths, equally spaced on a decibel scale, under each of two warning conditions, randomly ordered. In half the series the conditions were: "No warning" and "Zero warning" (i.e. warning and stimulus simultaneous), and in the

other half they were: "No warning" and "−0·5 sec." These series were regularly alternated. Six of the ten sessions also included one-and-a-half series under the "No warning" condition and one-and-a-half under the "−0·5 sec." condition. They were given in the following order (and its counterbalanced versions), where A and B represent "mixed" series, and Y and Z "unmixed series": A, B, Y, A, B, A, ½Z, ½Y, B, A, B, Z, A, B.

Results

Each set of twelve counterbalanced sessions were combined and subjected to probit analysis. The difference between each pair of thresholds, and its variance, was computed for each subject, and the weighted mean difference for all the subjects then calculated, as shown in Table IX. It can be seen that in each of the three conditions there is a significant fall in threshold when the warning is present. There is no significant difference between the different "No warning" conditions, nor between the two "−0·5" conditions, nor between the mixed −0·5 threshold and the zero threshold. The three "No warning" conditions were combined to give a value for the threshold (0·379 db.) from which the differences found were subtracted to give curve D in Figure 1.

The lack of significant differences between the "No warning" conditions excludes a "set" raising the "No warning" threshold as compared with an unlowered −0·5 sec. threshold in the mixed conditions.

In calculating the reaction times (based on 934 positive responses) seven disproportionately long (above 3 sec.) reaction times were omitted in calculating the reaction time for the "No warning" condition in the series where it is mixed with the −0·5 sec. condition. The number of stimuli on which each false positive rate is based is given in brackets after it.

Figure 2 provides further evidence that the threshold change is produced by a specific effect of the warning. The total distributions of positive reaction times in the "No warning" conditions of mixed series A and B are given in Figures 2B and 2C. In Figure 2B the dotted curve represents the excess number of positive reactions for each duration of reaction time when the "No warning" reactions are subtracted from the "−0·5" reactions. In Figure 2C they are subtracted from the "0" reactions. In the latter case there is no evidence of the excess being delayed, in the former they are clearly delayed.

Although Figure 2B shows a "negative deflection" for reaction times less than 0·5 sec., as did Figure 2A, this is not significant at the 5 per cent. level on the one-tailed binomial test (Siegel, 1956).

Discussion

The results of Experiment 1(*a*) did not show any significant change in the standard deviation of the threshold with variation in the warning interval. The results are in accord with the threshold fall with decrease in warning interval previously reported (Howarth and Treisman, 1958) which is given by both psychophysical methods used. In Experiment 1(*b*) only one subject showed any significant departure from parallelism of the regression lines. In each part of the experiment, taken as a whole, there was no significant departure from parallelism, and therefore no evidence of change in S.D. with warning interval.

This is further confirmed by Experiment 2(*c*). The results of Experiment 2 as a whole show no point of inflection as the warning period decreases, but a continual fall in threshold down to the zero interval.

In Experiment 3 a negative warning effect was shown which could not be attributed to set (Experiment 3(*d*)).

Of these three results the first is the most difficult to assess. It might be that the predicted change in the standard deviation of the response was obscured by greater sources of variability in the conduct of the experiments, but as the effect, if present, should have been fairly large, this is unlikely. Moreover, in making this prediction, sufficient attention was not given to the question of the appropriate scale of measurement. Equal intervals at different points on a linear scale would be unequal on the corresponding logarithmic scale. The problem of the appropriate psychophysical scale should therefore be clarified before this prediction is considered further.

It is interesting to note, however, that the assumption of a constant standard deviation led Tanner and Swets (1954) to the conclusion that the psychophysical scale for light intensity was an integral power function which seems on general grounds rather implausible.

The fall in threshold to a minimum with the simultaneous warning, and the very interesting retroactive effect of the warning, suggest that the decision should not be considered as uniquely determined by some aspect of the subject's physiological state at the moment of arrival of the stimulus. Rather it seems that inputs can be stored until the occurrence of the warning signal, provided the interval is not too long, so that both can have an effect in determining the response.

The relative constancy of the false positive rate as the threshold is lowered, in our experiments, as compared with the increased false positive rate when the threshold falls in the experiments of Tanner and Swets (1954) and Barlow (1956) suggests that the effect of our extra signal is in some way to reduce the noise from which the stimulus must be discriminated, most probably by reducing the subject's uncertainty about exactly when the stimulus is likely to occur.

References

Barlow, H. B. (1956). Retinal noise and absolute threshold. *J. opt. Soc. Amer.*, **46**, 634–9.

Finney, D. J. (1952). *Probit Analysis.* London.

Howarth, C. I., and Treisman, M. (1958). The effect of warning interval on the electric phosphene and auditory thresholds. *Quart. J. exp. Psychol.*, **10**, 130–41.

Siegel, S. (1956). *Nonparametric Statistics for the Behavioral Sciences.* New York.

Tanner, W. P., and Swets, J. A. (1954). A decision-making theory of visual detection. *Psychol. Rev.*, **61**, 401–9.

Woodrow, H. (1930). The reproduction of temporal intervals. *J. exp. Psychol.*, **13**, 473–99.

A TEST OF THE NEO-BEHAVIOURISTIC THEORY OF EXTINCTION

BY

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A test between Moltz's and Deutsch's theory of extinction was devised. Animals were trained to go to the same goal-box via two different paths. Then they were divided into two groups. The first found the goal-box empty, the second found the entrance into the goal-box blocked. The choices of the animals on the next trial were observed. The results are those predicted by Deutsch.

Moltz (1957) has recently proposed a Hullian explanation of the facts of latent extinction. Deutsch (1953, 1956) has proposed an explanation of these phenomena in terms of his own theory. According to the Hullian view, the tendency to repeat a response diminishes when it has been executed and its performance has not been followed by a reward. Reactive inhibition (IR) and conditioned inhibition (S^IR). are assumed to produce extinction by jointly opposing the reaction potential (S^ER). However, there are cases in the literature of latent extinction (for instance, Seward and Levy, 1949, Deese, 1951). In these experiments an animal's tendency to execute responses leading to a goal is reduced when it is placed in the goal and it is shown that this goal no longer contains the desired reward. The responses leading to this goal show a tendency to extinction even when they have not been executed. Moltz suggests that the reason for this is that antedating goal reactions repeatedly occur in the goal-box and, as they are not followed by reward, they suffer extinction. As these antedating goal reactions occur as ingredients of the stimulus-response chain leading to the goal, they will not be evoked even at the beginning of this stimulus-response sequence. If they are not evoked or evoked at a reduced strength, their characteristic proprioceptive stimuli will undergo diminution also. Therefore a part of the stimulation which normally evokes the responses leading towards the goal will be missing and partial extinction will have taken place.

According to Deutsch's theory, extinction does not depend on response evocation at all. It is one of the deductions from this theory that extinction is brought about by the failure of one stimulus to follow another which has usually preceded it. Another deduction is that all the stimuli on the side of the break further from the goal will undergo a diminution in attractiveness; for instance, if food is left out of a goal-box and this is shown to a rat which has been running to the goal-box for this reward, then the cues at the beginning of the maze should be affected by this experience.

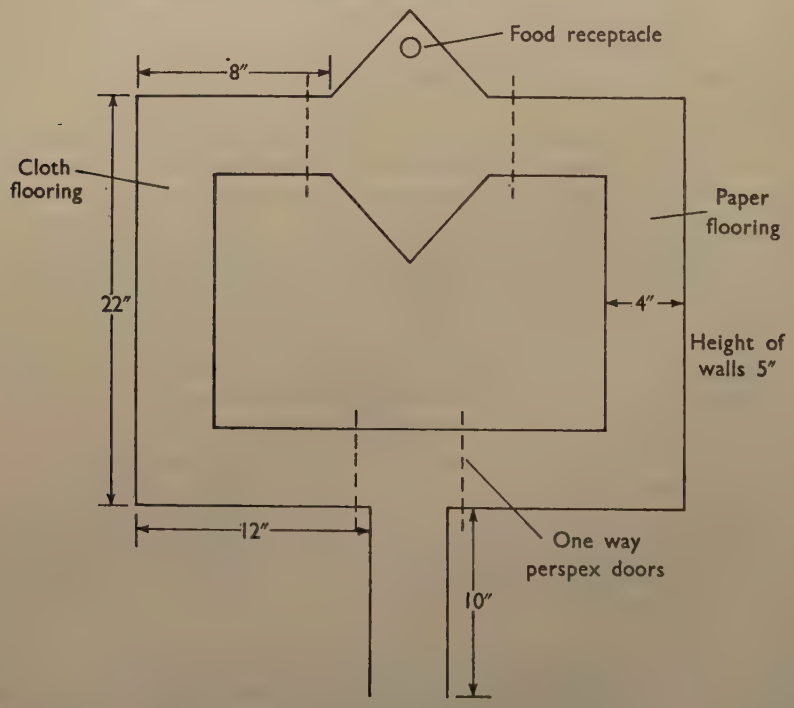
As both Moltz's and Deutsch's theories will predict the existing data on latent extinction, some independent test of their merits was thought to be desirable. Therefore a test of the following form was devised: A maze was constructed with two alternative routes of the same length leading to a common goal-box. There were doors just past the choice and in the goal-box to prevent retracing. Rats were given a free choice of path and were rewarded by food in the goal-box, whichever choice they made. In extinction, two different procedures were used. The first

* Working with a grant from the Medical Research Council.

consisted of leaving the goal-box empty. According to the neo-behaviouristic view espoused by Moltz, the antedating goal reaction (r_g) should be aroused by the goal-box and suffer extinction as reward does not follow. This extinction should affect the stimulus-response sequences corresponding to the two routes equally. The r_g–s_g components of the habits should be knocked out to the same degree in both paths. Therefore Moltz's addition to Hull's theory should not help us to make a prediction and we are thrown back on the orthodox stimulus-response interpretation. According to this theory, reactive inhibition will lead to the extinction of a response which has been performed unrewarded. Hence the turn which has just been made previous to the entry into the empty goal-box should be extinguished, whereas the response of going via the alternative route should be unaffected. Therefore, having made one response which has been unrewarded, the animal should make the other and go via the other equally short route. Hence the neo-behaviourist should predict alternation provided that the animal was distinguishing between the two responses. Deutsch, on the other hand, would say that both stimulus series had been interrupted by the rats' experience in the goal-box and that therefore alternation should remain at the pre-test level.

FIGURE 1

PLAN OF MAZE



In the second condition, extinction was produced by blocking the paths leading to the goal-box just before the entrance to it. Here both theories would expect alternation, but the group was run to demonstrate that the animals had indeed distinguished the two alternative routes. The two conditions (goal-box empty, path blocked) are very similar from the Hullian point of view, but quite different on Deutsch's theory.

Experimental Design and Procecure

A simple two-choice maze was constructed from steel segments with paths of equal length leading to a common goal-box (Fig. 1). One-way perspex doors were fitted at the beginning and end of each path and the floors of the paths were differentiated with cloth and paper. The maze was covered in with wire netting. The subjects used were nineteen hooded rats (eight male, eleven female) varying in age from 3 to 4 months, with no previous experience of experimental situations. All the animals were thoroughly tame, having been handled frequently from an early age.

Each animal, after 22 hr. food deprivation, was given four consecutive training runs per day and allowed to remain in the goal-box, where a reward of food was available, for 20 sec. The time taken to remove the animal by hand and replace it at the beginning of the maze was kept constant. Delays at the choice-point were recorded.

After 8 days training the rats were split up into two groups, A (ten animals) and B (nine animals). (Apart from the inclusion of four males in each group the division was arbitrary.) For Group A wooden blocks were inserted in both paths just before the entrances to the goal-box, and for Group B food was removed from the goal-box to which access was still available via the paths.

Each animal was given four consecutive test runs on the ninth day. In the case of the A group rats they were allowed to remain for 20 sec. in the blocked pathway Similarly, the B group was allowed 20 sec. in the empty goal-box. After a further 6 days of normal training runs a further test was conducted with the roles of the groups reversed.

Results

The figures given in Table I indicate the number of animals in each group which alternated between the first and second consecutive runs in the two test situations. The average number of animals alternating between the first two runs, calculated on the total of 14 days training runs, was 8·8 ($\sigma = 2{\cdot}15$). It can be seen that the number of alternations made when the goal-box is empty does not differ from this average figure.

TABLE I

	Goal-box empty	*Path blocked*	*Significance of difference*
Group A ..	3	10	$\chi^2 = 7{\cdot}912 : P < 0{\cdot}01$
Group B	6	7	(Difference in expected direction but not significant)
Total	9	17	$\chi^2 = 5{\cdot}968 : P < 0{\cdot}02$

(Yate's correction has been applied in the calculation of χ^2 values).

The cloth flooring in one of the two alleys is responsible for the low amount of spontaneous alternation. This covering induced a preference for that alley in the animals and kept low any tendency to spontaneous alternation. This tendency would have masked the effect which the experiment was designed to show.

Delays at the choice-point are listed in Table II, from which it can be seen that the results cannot be attributed to influence on the amount of random behaviour caused by differences in delay.

TABLE II

DELAYS AT THE CHOICE POINT ON TEST RUNS

		Delay in seconds										
		1	2	3	4	5	6	7	8	9	10	11
Condition A (paths blocked)	Before alternation ..	12	2	1	1	–	–	–	–	–	–	1
	Before same path choice	2	–	–	–	–	–	–	–	–	–	–
Condition B (goal-box empty)	Before alternation ..	4	1	–	1	1	1	–	–	–	1	–
	Before same path choice	7	2	–	–	1	–	–	–	1	–	–

(If those animals showing excessive delays at the choice-point are omitted in the calculation of χ^2 on the grounds that their behaviour is likely to be random, the value of P given in Table I is not materially affected).

DISCUSSION

It seems clear from the results that the neo-behaviouristic theory of extinction, if it has been correctly interpreted, cannot account for the result and that the prediction from Deutsch's theory is confirmed. It appears that it is not responses which are extinguished. It cannot be argued that the rats did not alternate when the goal-box was left empty because they could not distinguish the two paths or because of the amount of stimulus generalization. This is because in the test with the blocked paths seventeen out of nineteen rats alternated, showing clearly that the paths were well differentiated as far as the rats were concerned. It may be argued that the rats which found their way into the goal-box obtained more secondary reinforcement and would therefore be more likely to repeat their choice. However, the rats which ran as far as the block would also be obtaining secondary reinforcement, though perhaps not quite to the same extent, so that we should not expect apparently no effect in one case and a large effect in the other. The two groups should be much more alike than they are. It could be said, nevertheless, that antedating goal responses would be extinguished in the group with the goal-box empty, but not in the path-blocked group. Even if some difference could be erected by neo-behaviourists on this ground, such a line of defence is not open to Moltz, as he believes that the antedating goal reaction (r_g) is conditioned back to the choice-point along the alleys. Therefore the r_g should get extinguished not only by non-reward in the goal-box, but also by a block in the alley.

If Moltz's theory cannot be used to explain the present result, though it seems to demonstrate the same type of behaviour found in latent extinction studies, it may be doubted whether it is the correct explanation of extinction phenomena generally.

On the other hand, all the extinction phenomena which Moltz covers, and the results of the present experiment, can be deduced from Deutsch's theory. According to Deutsch's theory, when an animal learns, the receptor structures responsible for detecting the various cues are arranged in a certain order. This order corresponds to the order of the detection of the stimuli by the animal in the learning situation. This temporal order of the occurrence of stimuli is stored by the connection of units belonging to each of the various receptor structures (*a*). If the receptor units were

stimulated in turn, each unit was connected only to its two neighbours (except in the case of the first and the last). This connection carries excitation from one member of the row to the next in turn, so that when one unit in a row is excited, the excitation will be conveyed to all the other members (*b*). When a unit to which a receptor structure is attached is excited, the effector system of the animal will act in such a way as to maximize the excitation of the receptor structure attached to the unit. The animal will then be attempting to reach a sub-goal (*c*). However, only the unit which is farthest away from the source of the excitation will operate in this way, so that only the most distant sub-goal will be sought out (*d*).

As soon as another sub-goal nearer to the source of excitation is detected, then the unit, to which the receptor structure signalling this sub-goal is attached, will cease passing excitation to its neighbour (*e*). It will thus in its turn become the sub-goal farthest away from the source of the excitation, and will therefore be sought out.

The source of excitation is usually a unit first in the row, which is sensitive to a physiological factor like dehydration, and to which a receptor structure detecting the ingestion of water is attached (*f*). The messages from this last receptor structure act to depress the irritability of this first unit to the physiological factor.

Each unit in a row has a certain threshold of excitation. This threshold is lowered each time the unit is switched off by the cessation of the flow of excitation to it (which will occur when a sub-goal nearer the final goal is detected (*g*)).

If such a cessation does not occur then there will be a rise in this threshold. That is, this unit will be less excitable and so will not be so excited by a given amount of arriving excitation and will therefore also pass less excitation on (*h*).

This rise in threshold will only occur when the unit is receiving excitation but not transmitting it (*i*), so that it is controlling the effectors of the animal (according to *d* and *e*).

If there is more than one row of units excited, then one of the end units of these rows which is most strongly excited will control the effectors of the animal if the movements are incompatible (*j*). If they are compatible, both will.

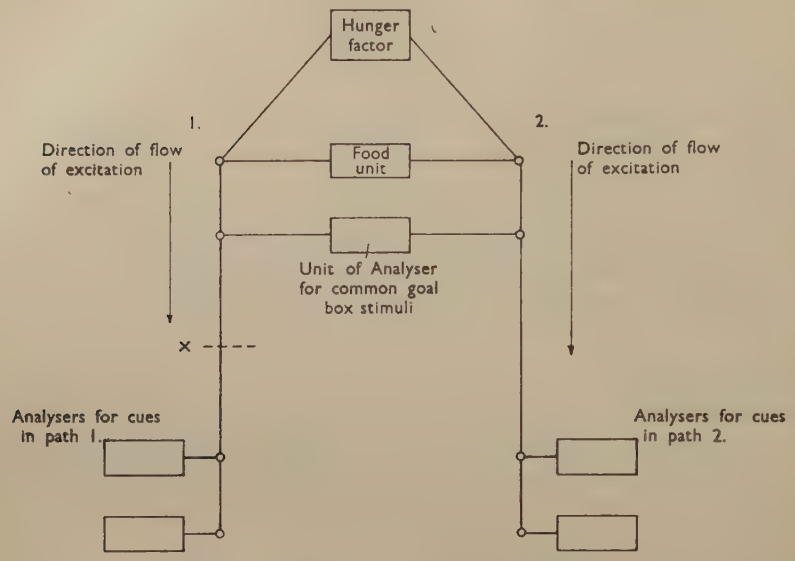
Now in the present situation two rows of units will be found each with the stimuli fastened to them in the order in which they occur in the two maze paths. The attachments to the first two units in both rows will be identical. The animal will detect the same cues (in the identical goal-box) before obtaining food. If the goal-box is empty, the food stimuli will not follow the stimuli from the goal-box. Hence the threshold of excitation of the second unit in both rows will rise (by *h* and *j*). They will therefore pass less excitation on in the future. Hence both rows will be affected at the same time and less excitation will be travelling down both the rows.

Hence there should be no greater tendency to alternate than usual as the attractiveness of the two sub-goals at the choice-point should be unchanged relative to each other.

However, if the stimuli down one of the two arms do not follow each other, then cues which are not common to the two sequences will not be succeeding each other in the usual way. Then the excitation past this break, down one row of units, will be attenuated (*h*). The other row of units will be unaffected as no break in the sequence of the stimuli in this row has occurred. Hence the balance will be shifted and the animal will choose the sub-goal with the greater amount of excitation (according to *j*).

This is what in fact happens in the present experiment (Fig. 2). Such an explanation can also be applied to the type of result obtained by Deese and by Seward and Levy. Deese rewarded rats on one side of a U-maze by giving them food. After

FIGURE 2



Condition A. When the animal chooses the path represented by the first row of links and the "goal box analyser" is not fired owing to the block at X, the threshold of the preceding links will rise and the excitation flowing down row 1 will diminish accordingly. Row 2 will remain unaltered and hence determine behaviour. Hence the animal should alternate between the first and second runs.

Condition B. Where the "goal box analyser" is fired and the food analyser is not fired, the threshold of both links attached to the goal box analyser will rise and the excitation flowing down both rows will diminish equally. Hence the animal's behaviour on the second run should not differ significantly from its behaviour on practice runs.

he had trained them the rats in the experimental group were placed in the empty goal-box for four 1-min. periods. These experimental animals, which were afterwards allowed to make their own choice, chose the goal-box, where food had previously been, a smaller number of times than the control group. The control group had had no latent extinction training. A break in the order of stimuli in the goal would diminish the attractiveness of the stimuli leading to this goal.

The above theory in contradistinction to Moltz's would predict a much more dramatic result in Deese's situation if both choices in the U-maze or a T-maze were rewarded. Then interrupting the sequence of stimuli in one goal-box should make the animals switch to the other goal-box on the next run. The effect in this situation should be as large as in the present experiment. Some preference for one of the paths should be induced to minimize spontaneous alternation in the training trials. Otherwise the tendency to switch should be very high anyhow (according to Deutsch, 1953, 1956). On the other hand, Moltz would have to treat this situation as analogous to the one obtaining in the experiment reported, for the antedating goal reactions (r_g) in this situation would be the same on both sides of the choice-point. This has been shown by Deutsch (1956).

Our thanks are due to the Medical Research Council whose generous help made this work possible.

References

Deese, J. (1951). The extinction of a discrimination without performance of the choice response. *J. comp. physiol. Psychol.*, **44**, 362–6.

Deutsch, J. A. (1953). A new type of behaviour theory. *Brit. J. Psychol.*, **44**, 304–17.

Deutsch, J. A. (1956). A theory of insight, reasoning and latent learning. *Brit. J. Psychol.*, **47**, 115–25.

Deutsch, J. A. (1956). The inadequacy of the Hullian derivation of reasoning and latent learning. *Psychol. Rev.*, **63**, 389–99.

Moltz, H. (1957). Latent extinction and the fractional anticipatory response mechanism. *Psychol. Rev.*, **64**, 229–41.

Seward, J. P., and Levy, N. (1949). Sign learning as a factor in extinction. *J. exp. Psychol.*, **39**, 660–8.

REASONING IN THE HOODED RAT

BY

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A problem situation was devised to test Deutsch's (1956) theory of reasoning. In this situation various problems can be set the rat and these problems admit of various equally rational solutions. Predictions from the theory were made, not only that the animals would solve the problems, but also which particular solution they would adopt. These predictions are confirmed. The rats were trained to run to two goal-boxes, one near, the other more distant. The near one had two paths of equal length leading to it, the more distant goal only one. After training, the animals chose the near goal-box on the first trial of the day. On the test trials the near goal-box was left empty, or the chosen path blocked, or a mesh placed across the goal-box, with the food accessible via the other short path.

It is possible to construct problems such that more than one solution of them is rational and admissible. From the results of such tests we can ascertain not merely whether an animal can solve the problem but also what the problem is to the animal, at least to a limited extent. Apart from the general interest of problem solving in animals, Deutsch has recently put forward a theory from which certain deductions follow about the behaviour of rats in reasoning or insight situations. From this theory it is possible to predict not only whether certain types of problems are soluble but also what type of solution will be preferred. To test this theory a situation of the following type was devised. A maze is made in which there are two goal-boxes. One of these goal-boxes is reached by a single long alley from the choice point; the other has two short, equal, paths leading to it. Now the rat is allowed on the training trials to go down any alley and it is always rewarded in whatever goal-box it has chosen. After it has become acquainted with the situation various problems are set to it. The first is to leave the near goal-box empty. To solve the problem of finding food, the animal must proceed to the other, more distant goal-box. The second problem is to block one of the two alleys leading to the near goal-box. To solve the problem of finding food this time, the animal can either go down the other short path to the near goal-box, or take the long path. Deutsch's theory predicts that it should take the other short path. The third problem is to place a wire mesh barrier across the near goal-box with the food just the other side of the mesh, so that the animal makes attempts to obtain it without succeeding. Here the animal can either take the other short path to the food, or go to the more distant goal-box. Deutsch's theory predicts that it should take the longer path. As this last prediction is somewhat at variance with commonsense expectation its verification constitutes an important success for the theory.

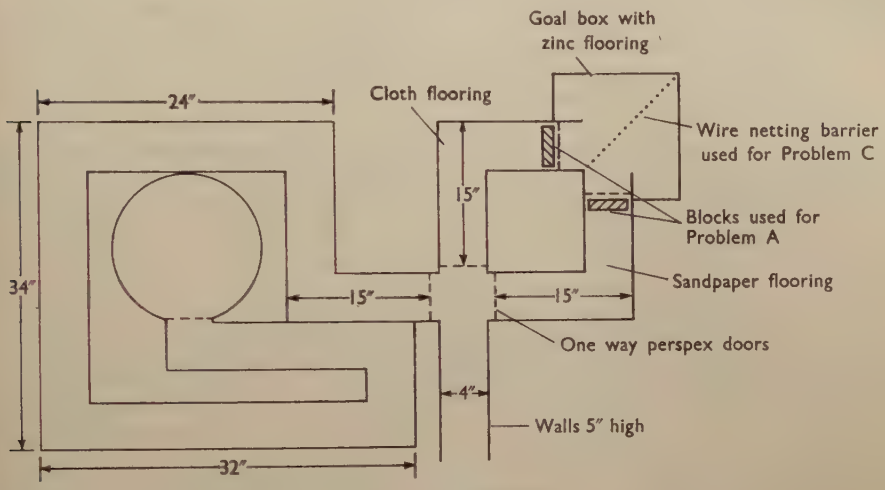
Experimental Design and Procedure

A three-unit maze was constructed from steel segments with the alleys so arranged that two short paths led to one goal-box and a third longer path to a different goal-box (Fig. 1). The design was such that from the choice point the animal was confronted with three paths of apparently equal length. Maximum cues were provided; the floors of the paths were differentiated with paper, sandpaper and cloth, and the goal-boxes and food

receptacles were of different shape. The flooring in one goal-box was perforated zinc and in the other paper. One-way perspex doors were fitted at the beginning and end of each path. The maze was roofed with wire netting.

The subjects used were twelve male hooded rats aged approximately 3 months. For a period of 18 days they were given three consecutive training runs per day after 22 hr. food deprivation. Within 6 days they were thoroughly tame and had lost all fear of the experimental situation. All, without exception, developed the habit of choosing one of the short paths on the first run of the day, and each animal gained some experience of all three paths. No runs were forced. Step 1 was conducted after 18 days: step 2 after a further period of 6 days' normal training runs, and step 3 after an additional period of 3 days' runs.

FIGURE 1



Step 1

Wooden blocks were placed in the short alleys for 50 per cent. of the subjects (Group 1). After encountering the block the animal was removed and replaced at the beginning of the maze. The block was removed from whichever alley the rat had not chosen. If this alternative short alley was chosen on the second run, the result was counted as correct. For the remaining 50 per cent. (Group 2) food was removed from the goal-box at the end of the short alleys. Animals were removed from the empty goal-box and replaced at the starting-point, after sufficient time had elapsed for exploration. The second run was counted as correct if the long path was chosen.

Step 2

This was a repetition of Step 1 with the roles of the two groups of subjects reversed.

Step 3

The goal-box at the end of the short paths was divided into two with a wire netting barrier. Whichever of these paths the animal chose he could gain entry to only half the goal-box, and food was always on the other side of the wire netting. Animals were removed after they had detected, and made definite attempts to get at, the food behind the barrier. Again they were replaced at the beginning of the maze. All twelve rats were used in this test. Second runs were scored as correct if the long path was chosen.

In all three steps, all animals continued their habit of choosing one of the short paths for the first run.

Results

TABLE I

Number of Second Runs in Accord with Theoretical Prediction

	Problem A (*path blocked*)	*Problem B* (*goal-box empty*)	*Problem C* (*goal-box divided*)
Group I (six rats)	5	3	4
Group II (six rats)	4	6	5
Total successes out of twelve possible on each problem ..	9	9	9

Number of animals succeeding on both Problems A and B = 7.
Number of animals succeeding on all three problems = 5.

It can be seen from Table I that the number of successes in the first Step (Group I path blocked, Group II goal-box empty) is greater than that in the second where the roles of the groups were reversed. Of the four animals who succeeded on the

TABLE II

Probabilities of Results being due to Habits Acquired on Training Runs

75 per cent. or more successes on Problem A	P = 0·000393
75 " " " B	P = 0·005096
75 " " " C	P = 0·01977

first and failed on the second, three failed by repeating their former solution. The probabilities given in Table II have been calculated from the probabilities of each rat solving each problem. For Problems A and B these individual probabilities were arrived at by counting the number of times in 6 days (the 5 days preceding the test run and the test run itself) that the animal had run a combination on the first and second runs which would have been counted as a correct result on the test run. (In the case of Problem C calculation was based on 4 days' runs.) Where goal-box alternation was the correct solution to the problem, the probability of a solution arising from habit has been assessed on the basis of the number of such alternations in the past. Where short path alternation was the correct solution a similar procedure has been adopted. This method gives maximum values for P, which would be considerably lower if calculations were based on the probability of the *particular* alley chosen on the first run of each test being followed by the alley counted correct on the second test run. It should be emphasized that the values given in Table II represent the chances of the choice of one alley out of three, calculated on the basis of the habits manifested during the training runs.

It may be objected (1) that an animal is most unlikely to repeat a choice which has just been unrewarded, and (2) as we are testing a theory which predicts a particular type of solution, we ought to test the probability of this solution against the probability of the other possible rational solution. This means that, on both objections, we should test the chances of one solution against the other, disregarding the third possibility, that of the animal repeating a run after non-reward. Accordingly, if

TABLE III

RECORD OF PAST RUNS FROM WHICH VALUES OF P HAVE BEEN DERIVED

	Problem A (path blocked)				*Problem B (goal-box empty)*				*Problem C (goal-box divided)*			
	Past 5 days' runs			*Test run result*	*Past 5 days' runs*			*Test run result*	*Past 3 days' runs*			*Test run result*
	x	*y*	*z*		*x*	*y*	*z*		*x*	*y*	*z*	
1.	2	3	0	*x*	2	3	0	*y*	2	1	0	*z*
2.	1	3	1	*y*	5	0	0	*x*	0	3	0	*y*
3.	0	1	4	*x*	4	0	1	*x*	2	0	1	*x*
4.	3	1	1	*x*	3	1	1	*x*	1	1	1	*y*
5.	2	3	0	*x*	2	1	2	*y*	2	0	1	*y*
6.	0	5	0	*x*	1	4	0	*y*	1	2	0	*y*
7.	0	5	0	*x*	0	5	0	*y*	1	2	0	*y*
8.	1	4	0	*x*	2	2	1	*y*	0	3	0	*y*
9.	1	0	4	*x*	0	0	5	*y*	3	0	0	*y*
10.	0	4	1	*y*	2	3	0	*y*	1	1	1	*y*
11.	0	0	5	*z*	1	4	0	*y*	0	2	1	*y*
12.	5	0	0	*x*	3	0	2	*y*	0	0	3	*x*
	Total correct runs 9				Total correct runs 9				Total correct runs 9			

x = short path alternation (correct for Problem A).
y = goal-box alternation (correct for Problems B and C).
z = choice of same path (incorrect for all problems).

Values of P were calculated by multiplying individual P values and adding to this figure the probability of any one animal failing, plus any two animals failing, etc.

we omit *z* runs in calculating the probabilities in Table II we arrive at the following result:—

TABLE IV

75 per cent. or more successes on Problem A	.. .. ..	0·0038
" " " " B	.. .. ..	0·0208
" " " " C	.. .. ..	0·0474

COMMENT

The prediction from Deutsch's theory is thus strikingly confirmed. The experiment seems free from the type of objection levelled at the Tolman and Honzik (1930) experiment, where response extinction may have been at least a factor. The success of the animals in solving the problem is probably due to the fact that blocking off of alleys was avoided during training because of the findings of an experiment by Deutsch and Anthony (1958).

Since the reasoning situation is in many ways theoretically similar to the extinction one described by Deutsch and Clarkson (1959) and since the senior author hopes to publish elsewhere a full statement of his theory, a detailed deduction of the results of the experiment will not be given here.

Our thanks are due to the Medical Research Council without whose generous support this work could not have been done. Mr. Clarkson is Dr. Deutsch's assistant under a grant from the Medical Research Council. We are also grateful to Mr. J. F. Scott of the Unit of Biometry, University of Oxford, for his advice on matters statistical and for his computation of the data.

References

Deutsch, J. A. (1953). A new type of behaviour theory. *Brit. J. Psychol.*, **44**, 304–17.
Deutsch, J. A. (1956). A theory of insight, reasoning and latent learning. *Brit. J. Psychol.*, **47**, 115–25.
Deutsch, J. A., and Clarkson, J. K. (1959). A test of the neo-behaviouristic theory of extinction. *Quart. J. exp. Psychol.*, **11**, 143–8.
Deutsch, J. A., and Anthony, W. S. (1958). Blocking the incorrect alley in a two drive learning situation. *Quart. J. exp. Psychol.*, **10**, 22–7.
Tolman, E. C., and Honzik, C. H. (1930). 'Insight' in rats. *Univ. Calif. Publ. Psychol.*, **4**, 257–75.

THE HULL-LEEPER DRIVE DISCRIMINATION SITUATION—A CONTROL EXPERIMENT

BY

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An experiment was conducted testing the author's explanation of the discrepancy between results obtained by Hull and Leeper in a similar situation. Animals were run either hungry or thirsty to obtain the appropriate reward by making one response when hungry and another when thirsty. For all groups the reward was in the same goal-box. The first group (Leeper) had the goal-box divided with each side being accessible only if the animal had made the correct response initially. The second group (Hull) had the same goal-box for both rewards, but if the wrong path was taken the animal was prevented from reaching the goal by a block. The third group had the same goal-box for both rewards again, but the animal could reach the goal-box even if the wrong path was taken and discovered the unwanted reward in the goal-box. The results confirm the predictions made from the author's theory.

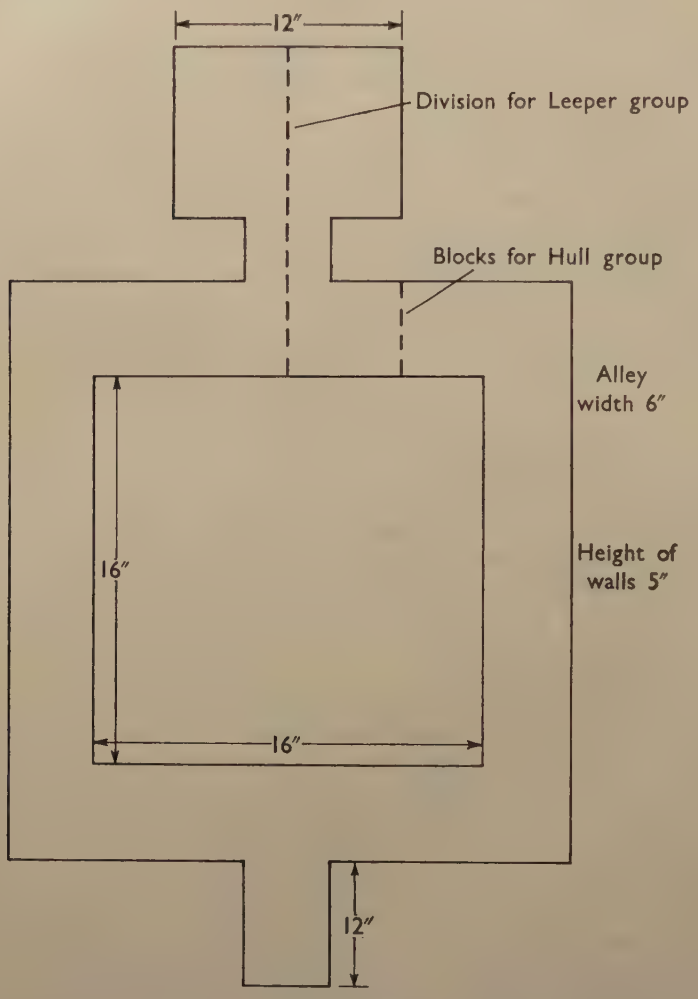
Introduction

It is over 20 years since Hull (1933) and Leeper (1935) concluded their studies to test whether rats can be taught to make different responses in a constant external situation as a result of changes in their motivation only. Hull and Leeper obtained widely discrepant findings. Hull found that there was almost no learning in the first few months of training, and only about 77 per cent. accuracy in the first 200 days of training on the first trials with five trials a day. On the other hand, Leeper's rats attained an accuracy of over 90 per cent. on the first trials at the end of only 20 days with five trials a day.

To what was the discrepancy due? The situations used were highly similar. The animal had to learn to go one way when hungry to obtain food and another way when thirsty to obtain water. Leeper states (1935):—"These experiments involved exactly the same procedure and apparatus . . . except that in Experiment IIIC there was a double end-box, and on an incorrect run the rat could enter the wrong end-box and see the undesired goal material in it before it retraced its steps to the correct arm of the maze; whereas in Hull's experiment and in Experiment IIIA, when a rat ran incorrectly, its steps led it to a closed door which barred its way into the one end-box, and the rat had to retrace its steps as though out of a simple cul-de-sac." Leeper then goes on to explain the difference between the two groups and comes to a conclusion which has been widely quoted and accepted. "Now to a hungry rat, it is probably no greater punishment to be turned back by a door (as in Experiment IIIA) than to be turned back by an end-box containing only a pan of water. Nevertheless this one difference in the situation seems to make an enormous difference to the rate of mastery of the problem. It would seem, therefore, that the rats must learn almost as much from their incorrect responses as they do from their correct responses." There are two curious slips in Leeper's reasoning here. He states "that this one difference in the situation seems to make an enormous difference," forgetting that there is another difference which he himself has mentioned. This is that in one situation there were two goal-boxes and in the other only one. The other strange statement is that "the rats must learn as much from their incorrect responses as they do from their correct responses." However, if the sight of the irrelevant reward had been the only factor, as he considers it to be, he should have concluded from his figures that the rats must learn a great deal more from their incorrect

responses than they do from their correct responses. (The slip is even more curious as on a cognitive theory he could equally well have concluded that the goal-box was important.)

FIGURE 1



Plan of Maze.

Before we can come to these conclusions on the basis of these experiments, there are further controls which must be performed. On the writer's (1956) theory, the divergencies of Hull's and Leeper's results could have been predicted. Accordingly, in addition to repeating Hull's and Leeper's experiments, a Control Group was run firstly as an independent check to the theoretical interpretation and secondly to ascertain the causes of the behaviour of the rat in a situation, which though simple and basic, has received scant attention. A group of rats was run which was given either food or water in a single goal-box depending only on the path taken to the goal, irrespective of motivation. Thus each animal would be presented with either the relevant or irrelevant reward on each trial, both appearing in the same goal-box, though never at the same time. In Hull's experiment, which was also repeated, it

may be recalled that each animal was only given experience of the goal object which was relevant, and this only if it had taken the correct path. If it took the incorrect path it was met by a block. In Leeper's experiment, on the other hand, the animal saw either reward whether it happened to be relevant or irrelevant, but always in a separate goal-box.

Subjects and Apparatus

The subjects were twenty-one male hooded rats, 4 months old. These were divided into three groups of seven. These were run in a maze constructed out of steel sections, and covered with wire netting (see Fig. 1). For one group (Leeper) the goal-box was divided into two by the use of a removeable perspex screen. For the second group (Hull) a perspex block was inserted in either one of the arms of the maze, depending on whether the animals were hungry or thirsty. For the third group no additions were made to the maze except that if an animal ran one way a food cup was immediately placed in the goal-box so that it would be waiting for the animal when it arrived, and if an animal ran the other way then a water cup would be inserted by the prestidigitatory efforts of the experimenter.

Procedure

All the animals were treated in the same way. They were maintained on a schedule in which they were deprived of water or food in irregular alternation for 23 hr. each day for the first 12 days. From the thirteenth to the twenty-eighth day hunger and thirst alternated regularly. It is for this period of regular alternation that results are given. Each animal was given four trials a day. A trial was counted as correct if the animal had not proceeded further than the third turn in the maze. If a correction was made spontaneously by the animal before it could see that its choice had led it to the block (in the Hull Group) it was counted as correct. This criterion, based on the same point in the maze, was adopted for the other two groups. If the animal ran past this point, it was not allowed to correct. (Hull allowed his animals to correct, but this was not possible here because of the control group which had no blocks.)

The animals were divided into three groups:—

(1) *The Hull Group.* The animals in this group met a block in the final section of the square maze if they did not make a response appropriate to their need state (right for water and left for food). Otherwise, they were rewarded, hungry or thirsty, in the same goal-box.

(2) *The Leeper Group.* The animals in this group ran to two goal-boxes, made by dividing the final length of alley and goal-box by a perspex screen. They were allowed to reach either box irrespective of their need state. One goal-box always contained food and the other always water.

(3) *The Control Group.* This group was allowed to reach the goal-box irrespective of its need state and given either food or water depending only on choice of alley. The goal-box for this group was not divided nor did the animals meet any blocks.

Results

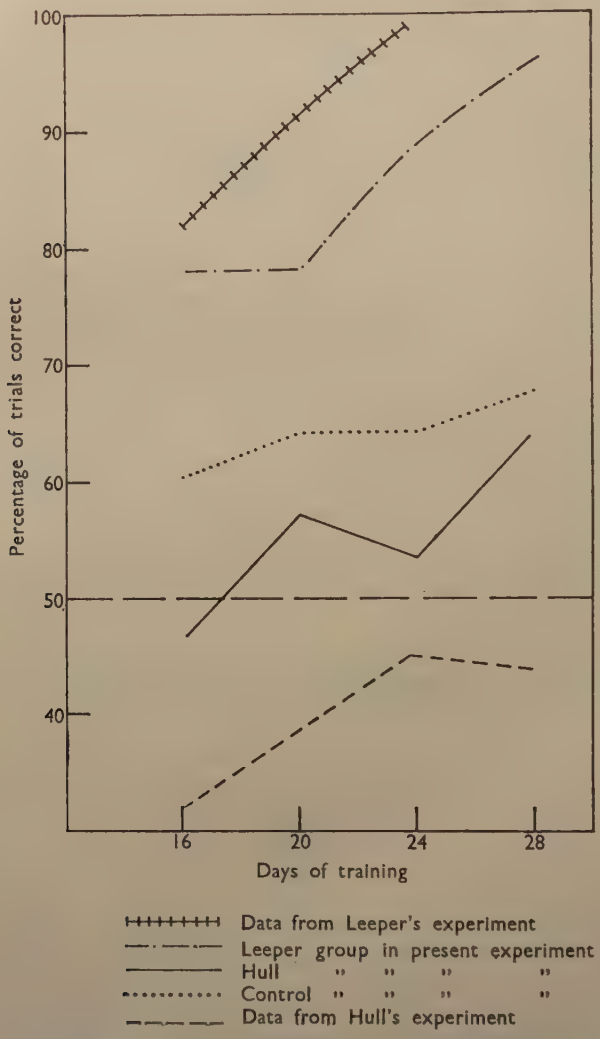
The results are summarized in Table I.

TABLE I

	Leeper Group	*Significance between L. and H. Groups*	*Hull Group*	*Significance between H. and C. Groups*	*Control Group*	*Significance between C. and L. Groups*	*Leeper Group*
Total errors	61	$t = 4{\cdot}79$ $P < 0{\cdot}001$	133	$t = 0{\cdot}012$ $P = 1$	135	$t = 4{\cdot}44$ $P < 0{\cdot}001$	61
Errors made on first trial of the day over 16 days	16	$t = 5{\cdot}54$ $P < 0{\cdot}001$	50	$t = 1{\cdot}5$ $P < 0{\cdot}2$	40	$t = 4{\cdot}13$ $P < 0{\cdot}01$	16
Proportion of successive errors out of total possible successive errors	0	—	8·93%	$t = 3{\cdot}79$ $P < 0{\cdot}01$	33·33%	—	0

Figure 2 shows the amount of learning, measured by first trial of the day successes, over 28 days. Figure 3 shows learning measured by percentages of total trials correct. (The results are here presented in a form which admits comparison with the original data of Hull and Leeper.)

FIGURE 2

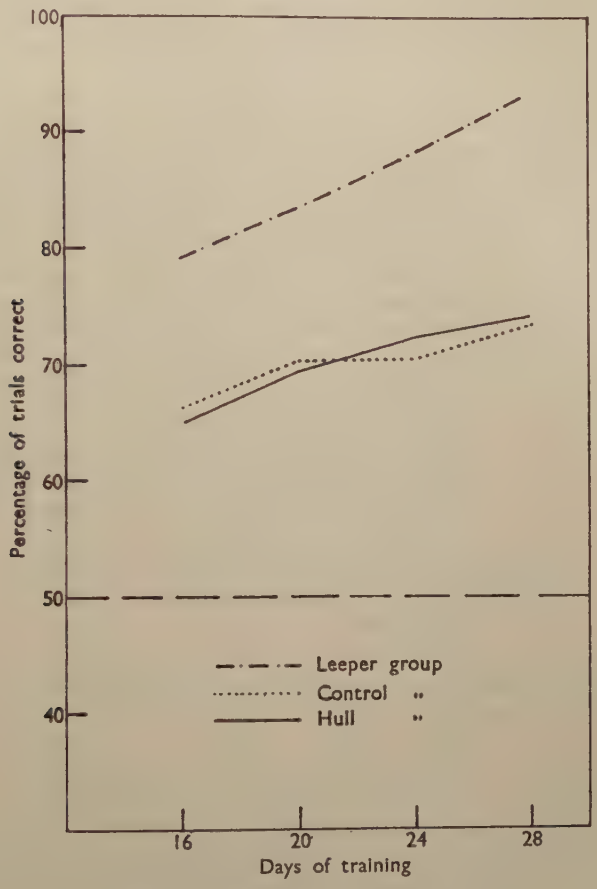


Percentages of first trials of the day correct. Comparison of Hull's and Leeper's original data with results of the present Experiment.

If we take the total number of correct choices made on 16 days (after a preliminary period of 12 days) then the Leeper Group is significantly superior. The animals in this group scored 387 correct against 315 correct of the Hull Group and 313 correct of the Control Group. The last difference is not significant. So from one point of view, Leeper was wrong. Seeing the reward when it is irrelevant does not seem to help the animal. If we use this criterion of learning, it does not seem "that the rats

must learn almost as much from their incorrect responses as they do from their correct responses." In fact from the present result we might safely conclude that they learnt nothing at all from seeing the reward when it is irrelevant. (Of course, they do learn something, but this experiment is a bad situation for showing it.)

FIGURE 3



Percentages of total trials correct.

However if we take the criterion of first trials on each day correct the situation changes somewhat. Here the Leeper Group scores 96 trials correct out of 112. The Control Group scores 72, whereas the Hull Group makes only 62 correct first runs. Here then seems to be some evidence for Leeper's assertion. But it is difficult to accept these figures as evidence of a greater speed of learning in the Control Group. The first trial correct score may here be determined by the regularity of the alternation between conditions. The Hull Group "learns" much faster during each block of trials. This is significant at the 5 per cent. level. This may be shown by comparing "total runs correct" for the Hull and Control Groups:—

	First trial in day	Second	Third	Fourth
Hull Group ..	62	73	89	91
Control Group ..	72	75	84	82

The reason for this is the differential rate of error repetition in the two groups. The Hull Group seldom repeats an error. Only in 9 per cent. of the cases where there could be successive errors were these actually made. But for the Control Group the figure is 33 per cent. and the difference is highly significant. Again, we must disagree with Leeper when he says that "it is probably no greater punishment to be turned back by a door than to be turned back by an end-box containing only a pan of water." There does seem to be a large difference due to the two effects.

Discussion

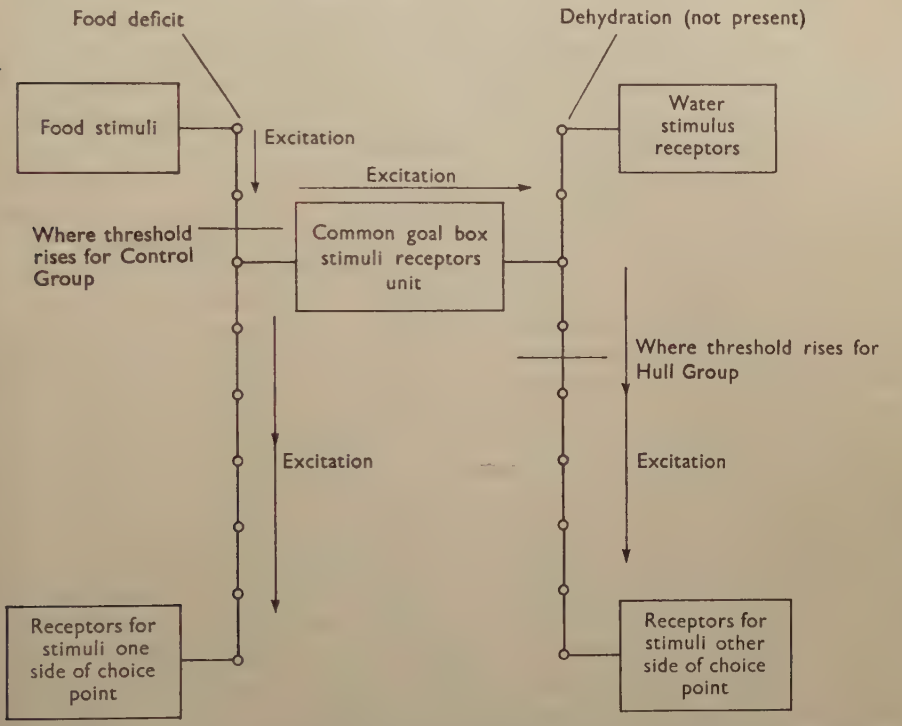
While no clearcut decision can be reached if we persist in talking in commonsense terms about learning in this situation, it might be instructive to see if a more satisfactory view of the experimental results can be gained from a theoretical standpoint. For Hullian and neo-behaviourist theory this makes one more of the many very simple and basic learning phenomena which it cannot explain. Whilst Hull (1952) gives an explanation of the differential utilization of drive cues when these do not occur together, on such an explanation we should expect no difference in the rate of learning depending on whether the animal runs to separate goal-boxes or to one goal-box. Briefly, if an animal is thirsty and it is rewarded by drinking when it has turned left, then thirst stimuli in conjunction with others from the maze will produce a left turning response. A right turning response to food is produced by an analogous mechanism. Whether the rewards are administered both in the same place or in two different places should make no difference on this reasoning (and no considerable difference even if r_gs and secondary reinforcement are brought in). On the writer's (1953, 1956) theory the results are predictable in considerable detail. It is assumed that, as an animal learns, the receptor mechanisms are arranged in the order in which they are stimulated by the environment. Each receptor mechanism and the unit to which it is attached become one in an ordered row of units. The end unit in one such row is sensitive to a particular physiological deficit like dehydration and is innately connected to receptors in the mouth and throat which meter water intake. When this end unit is excited, the excitation is transmitted to the next unit and so in turn to all the units in the row. The last unit in the row which is excited will determine what sub-goal is sought, by giving tropistic attraction to the stimulus which stimulates the receptor mechanism attached to it. However, once a sub-goal nearer the final goal is registered, then the excitation transmitted by the unit which underlies it will cease to be passed on and all cues or sub-goals further away from it will lose their power to evoke a tropistic response.

If one unit is not switched off within a certain time by the cessation of transmission through a unit nearer the final goal, its threshold of excitation will rise. This means that if cue B does not any longer follow cue A, as it had always done, then less excitation will pass to the unit underlying it, causing the animal to be drawn less vigorously to cue A, and causing other cues to be relatively more attractive as sub-goals. The cue with a unit underlying it which is more highly excited will be selected by the animal. As excitation is passed from one unit to another, once this excitation has suffered attenuation through the raising of a threshold of one of the units which passed it on, it will be passed on in this attenuated form. Further, if a unit and its receptor mechanism is a member of two rows of units simultaneously, this excitation will be transmitted through it from one row to the other. This sketch of the theory is incomplete but should be sufficiently good for an understanding of the explanation which follows. A fuller account is to be found elsewhere (Deutsch, 1953, 1956).

Now in the present situation the theory, as opposed to Hull's, would predict a large difference between the group which was rewarded in two different goal-boxes and the two groups where both choices led to the same goal-box. For the Leeper Group, if we consider the learning at and after the choice point, the two rows of units to which the receptoral mechanisms were attached can be separately excited as no receptoral mechanisms representing cues will be attached to both rows simultaneously. Therefore if the row to which the receptors representing the sub-goals leading to water are attached is excited when the animal is thirsty, it will be only this set of sub-goals which is attractive when the animal is at the choice-point.

FIGURE 4

Diagram of theoretical mechanism when animal in Hull or Control Group makes wrong choice when it is hungry.



When animals in the Control Group find no food, excitation to both rows decreases. When animals in the Hull Group meet a block before the common point, only excitation flowing to the end of one row is lessened.

However, if there is a common point shared by the two paths after the choice point the situation becomes entirely different. Any excitation generated in one row will be transmitted by the units of the receptor mechanism common to both rows. Hence whichever row of units the excitation originates from, it will spread to the sub-goals on the other row also, so that both sets of sub-goals—those leading to water and those leading to food—will be simultaneously excited. Hence, though the animal will have "learnt" in one sense it will not be able to perform. Nor as the explanation stands will it be ever able to manifest learning, which it does.

However, this ability may be explained in the following way. There may be other features besides those which are common to the two sequences which are picked out by the animal when it enters the goal-box. For instance, it will be looking at the goal-box from two different angles as it enters. This would mean that the excitation would not be transferred in its entirety from one sequence to the other. The proportion transferred from one sequence to the other in this way will remain fixed by the proportion of the total number of units in common in the two sequences. However, as learning proceeds, the proportion transmitted directly from link to link would be expected to rise after each rewarded trial. There would thus be a progressive increase of the absolute difference between the competing units at the choice-point. The manifestation of learning would therefore be slow. There is some basis for this suggestion if we compare the results in the present experiment with those of Hull. His animals showed much less learning and it can be seen from the maze he used that his maze would not give the animal so much opportunity of seeing the final common segment and goal from different angles.

On the other hand, it must be stressed that his maze was also much larger and a greater distance intervened between the reward and the animals' choice. If this was to be shown to be a factor in the situation we should have to explain the rats' ability to learn in terms of conditional learning.

So far we have explained why there should be a difference in the speed of learning depending on whether there are two goal-boxes or only one. It remains now to account for the differences between the Hull and Control Groups. In the Hull Group, where the animal comes up against a block, the threshold of excitation of a unit in a row will rise as the usual sequence of sub-goals has not occurred. This unit is in a part of the row downstream of the excitation reaching it from the common receptor mechanism. Hence the excitation transmitted by the common receptor mechanism from the other row will suffer attenuation as it travels down the row of units where the "block" occurred. Hence there will be a considerable discrepancy at the end of the two rows in the amount of excitation and the cue whose underlying excitation is larger will be chosen. Hence if an animal in the Hull Group makes a mistake it will be much less likely to be followed by another than in the Control Group. For in the Control Group neither of the rows will be affected differentially by a mistake after the point where the common receptor mechanism spans them. Therefore the excitation transmitted to the units underlying the cues at the choice-point will not alter in its proportion. Therefore the tendency to repeat a mistake will be much larger and the rate of "learning" within a block of trials much smaller.

On the other hand, the number of first trials correct after a switch in motivation will be larger in the Control Group. For in the Hull Group the experience of the block in the now correct alley will still have some attenuating effect on excitation passing down that particular row of units.

The theory is thus able to predict all the salient points in the experiment. It may be asked why the Control Group received no real benefit from its experience with the irrelevant reward. Though Leeper may have been wrong in this instance, it has been shown in other experiments, such as those of Spence, Bergmann and Lippitt (1950), that experience of an irrelevant reward does lead to learning. Why should it have not led to learning in this instance? Any such learning would not become apparent in this situation as can readily be seen by a reference to the theory. An improvement in performance in this situation results from a differential excitation arriving at the units underlying the choice-point. Any increment in the amount of excitation passed owing to a greater number of reinforcements above the units to

which the common receptor mechanisms are attached, is of no avail as this excitation will merely be impartially distributed to both rows of units through the common units.

The above series of experiments are complementary to the study of Deutsch and Anthony (1958). The theoretical interpretation of the present experiments is corroborated by the findings of that study. Some of the considerations explaining especially the behaviour of the Hull Group are there tested in a somewhat different situation.

References

Deutsch, J. A. (1953). A new type of behaviour theory. *Brit. J. Psychol.*, **44**, 304–17.

Deutsch, J. A. (1956). A theory of insight, reasoning and latent learning. *Brit. J. Psychol.*, **47**, 115–25.

Deutsch, J. A., and Anthony, W. S. (1958). Blocking the incorrect alley in a two-drive learning situation. *Quart. J. exp. Psychol.*, **10**, 22–8.

Hull, C. L. (1933). Differential habituation to internal stimuli in the albino rat. *J. comp. Psychol.*, **16**, 255–73.

Hull, C. L. (1952). *A Behaviour System.* Yale University Press.

Leeper, R. (1953). The role of motivation in learning: a study of the phenomenon of different motivational control of the utilization of habits. *J. genet. Psychol.*, **46**, 3–40.

Spence, K. W., Bergmann, E., and Lippitt, R. (1950). A study of simple learning under irrelevant motivational reward conditions. *J. exp. Psychol.*, **40**, 539–51.

VISUAL DISCRIMINATION WITH A SINGLE MANIPULANDUM FOLLOWING TEMPORAL ABLATIONS IN THE MONKEY

BY

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The aim of this investigation was to determine what effect variation in the conditions of cue presentation and response availability has on the visual discrimination performance of monkeys with bilateral inferior temporal ablations. Six animals were trained on one of two versions of a test of successive brightness discrimination. Common to both versions of this test was the availability of a single lever, manipulation of which in the presence of the positive cue constituted the correct response. Performance on this test was compared with performance on a pattern discrimination, for which the customary simultaneous two-choice procedure was used. It was found that the temporal removals were followed by definite impairment on the pattern discrimination (as expected), but no consistent change in efficiency at brightness discrimination could be attributed to the lesions. Alternative interpretations, making reference to the amount of pre-operative training on the brightness discrimination or the lack of differentiation between the correct and alternative responses in this test, are discussed.

Introduction

Monkeys with bilateral inferior temporal lesions are, as a rule, impaired when required to select consistently between two formal response alternatives on the basis of two dissimilar and concurrent visual cues. It is established that the impairment in visual discrimination is not critically dependent upon the dimension along which the cues differ (e.g. size, brightness, hue or pattern), providing that the problem is of appropriate "difficulty" (Mishkin and Pribram, 1954; Mishkin and Hall, 1955). This parameter is defined by reference to the performance scores of unoperated animals on a given series of discrimination tests.

The conditions of cue presentation and response availability necessary for the manifestation of this discrimination deficit have not, however, been investigated as systematically as have the cue dimensions. An important exception to the predominant application of the classical "simultaneous" two-choice procedure (i.e. two cues with formal response alternatives are presented to the animal at one time) is the study of Pribram and Mishkin (1955). In their experiments only one of the two cues was presented on any given trial. The animal was required to make a given response in the presence of the positive cue and to avoid repeating this response when the negative cue was exposed. Under these conditions ("successive" discrimination) the post-operative deficit was at least as severe as with the simultaneous presentation of the same cues.

New conditions of cue presentation and response availability were devised for the present study. Using a Skinner-type automatic apparatus with a single manipulandum it was found possible to train monkeys to respond to changes in the overall luminance of an encompassing homogeneous field. The difficulty of this test could be graded by accurately varying the difference between the successive levels of luminance. Performance dependent on changes in overall luminance was contrasted with that

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dependent on an incremental light source superimposed upon a constant ground and with that on a standard simultaneous pattern discrimination. The aim of the investigation was to gain a wider understanding of the deficit which follows bilateral temporal ablations in monkeys by extending the range of test conditions.

Methods

Subjects

Six immature and experimentally naive rhesus monkeys were divided at random into two groups. Animals T_1–T_4 were subjects in Experiment 1, animals T_5–T_6 in Experiment 2. Animal T_3 died following surgery. The animals weighed between 5 lb. 5 oz. and 6 lb. 12 oz. when testing began.

Operations and histology

All animals were given one-stage bilateral inferior temporal lesions on completion of their pre-operative training. The surgical and histological procedures have been described elsewhere (Ettlinger and Wegener, 1958). Reconstructions of the lesions and representative cross sections for animals T_1 and T_5 are shown in Figure 1. The lesions in the remaining animals are essentially similar. Broadly speaking, the average extent of removal is probably smaller than in the study of Pribram and Mishkin (1955), more particularly in the posterior direction.

Apparatus

For the tests of brightness discrimination, a globe of flashed opal diffusing glass ($17\frac{1}{2}$.in. diameter) was mounted centrally in a large refrigerator painted white, so that the globe's opening (9 in. diameter) faced downwards. A cage could be placed under the globe and was fitted with a movable false floor. When the top of the cage was pulled back a monkey could be hoisted into the interior of the globe. A lever and food chute projected for 2 in. into the opening of the globe on the level of the false floor when at its highest position. At a height of $8\frac{1}{4}$ in. above the top of the globe a neutral density grating filter (20 in. by 20 in.) was installed. This could be silently varied by means of a cable mechanism and electrical motor housed in an adjoining room. Three G.E.C. circline fluorescent lamps ($8\frac{1}{4}$ in. diameter, standard cool white; 12 and 16 in. diameters, standard warm white) were mounted concentrically against a reflector at $9\frac{1}{2}$ in. above the filter, and supplied from a constant voltage source. A lens system, using the 16 in. tube as light source, allowed a disc of light ($\frac{9}{32}$ in. diameter) to be projected through the globe at $10\frac{1}{2}$ in. above the lever. A shutter, operated silently by cables from the adjoining room, controlled the exposure of this incremental light spot. Its luminance could be adjusted independently of that of the globe, the former by means of filters in the optical system, the latter by the large grating filter. A loud buzzer served to mask all extraneous sounds.

For the simultaneous pattern discrimination a modified Wisconsin General Testing Apparatus was used.

Experiment 1

Training procedure (see Table I).

Pre-operative criterion training. Animals T_1–T_4 were first trained, in progressive stages, to criterion on a successive brightness discrimination where two levels in the overall luminance of the globe served as cues. Each week the four animals were given 5–6 sessions lasting an hour in the globe. The luminance of the globe, measured in its interior, was 10 foot candles, $\pm$ 2 per cent. For 30 trials of 8 sec. duration, spaced at random within each session, the luminance was raised to 73·8 foot candles, $\pm$ 2 per cent. If the animal pressed the lever 5 or more times during any such 8 sec. period of increased luminance, it was rewarded with one 0·5 gm. pellet of Purina chow passed automatically down the food chute. Only one pellet was made available, irrespective of the number of presses greater than 5, so that the maximum number of rewards on any one day was 30. Criterion performance consisted in (*a*) obtaining at least 81 out of a maximum of 90 rewards on three successive test days, *and* (*b*) pressing the lever below an average rate of four times per min. during the periods of 10 foot candle luminance on three successive days. Supplementary food (about 30 gm. Purina chow, 10 gm. shelled peanuts, 36 gm. orange) was supplied after each test session. This phase of training lasted $2\frac{1}{2}$–$3\frac{1}{2}$ months.

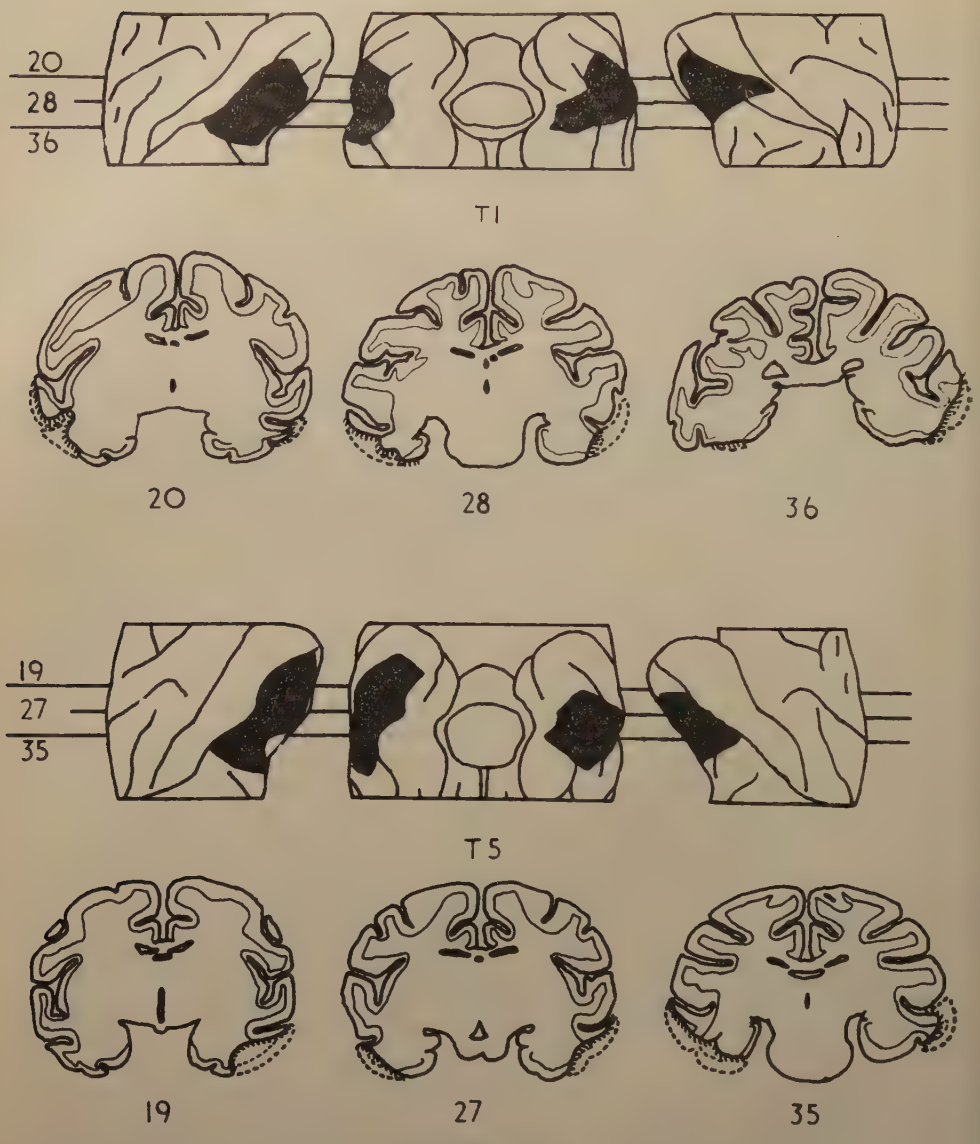

FIGURE 1

Reconstruction of the brains of animals T_1 and T_5, together with representative cross sections through areas of cortical damage. Black indicates the extent of the cortical removals on the surface views.

First pre-operative parametric run. After reaching criterion all four animals were immediately started on the first pre-operative parametric run in which the brightness difference was progressively diminished after each group of four test sessions (method of serial groups). During each daily session of one hour in the globe the overall luminance was still increased on 30 trials of 8 sec. duration to 73·8 foot candles, $\pm$ 2 per cent. The intervals between these 30 trials were randomly varied, but averaged 2 min. in duration. During the remaining 56 min. of each session the luminance of the globes was at a given level below 73·8 foot candles and was maintained constant for the four test sessions constituting a step. Thus for the first 4 days (step 1) the difference between the 8 sec.

positive cues (at 73·8 foot candles) and the 2 min. negative cues was 71·1 per cent. of the positive cue; on the next 4 days (step 2) the difference was 35·5 per cent.; for step 3 it was 17·7 per cent.: then 8·8 per cent.; for step 5 it was 4·4 per cent. and finally (step 6) 2·2 per cent. In every case a pellet of chow was provided as reward if the monkey pressed the lever 5 times within the 8 sec. period of the higher level of globe luminance. In order to avoid extinction of the habit as the brightness difference was diminished to below the animals' capacity, the series was terminated whenever *either* (*a*) an animal failed to obtain 40 rewards out of the maximum of 120 possible during any step, *or* (*b*) the ratio of the rate of lever pressing during the total exposure of the positive cue to the rate during the total exposure of the negative cue on any step, fell below 3. After failing to meet this criterion an animal immediately reverted to the conditions of step 1 for 4 days.

Pre-operative learning of pattern discrimination. Following completion of the first parametric run animals T_1 and T_3 were taught to discriminate between two patterns in the Wisconsin General Testing Apparatus. The positive cue was a yellow outline square ($1\frac{3}{4}$ in. by $1\frac{3}{4}$ in. with sides $\frac{3}{8}$ in. wide) painted on a grey ground. A yellow cross ($1\frac{7}{8}$ in. across, $\frac{7}{16}$ in. thick), likewise on grey, served as negative cue. Both cues were painted on the horizontally placed lids of food containers set 12 in. apart. Thirty trials were given each day, using a Gellerman schedule for random left/right positioning of the positive cue, a reward of half a peanut and a non-correction technique. The criterion for acquisition of this discrimination was 90 correct choices in 100 successive trials.

Second pre-operative parametric run. Animals T_1 and T_2 were given a second pre-operative parametric run, 14 days after learning the pattern discrimination in the case of the former, 14 days after completing the first parametric run in the case of the latter. Both started with step 1 and continued according to the procedure of the first run, reverting after failure once more to step 1.

Pre-operative retention of pattern discrimination. Immediately after completing the second pre-operative parametric run animal T_1 was retrained on the pattern discrimination according to the procedure and criterion of original learning.

Operations. Animal T_1 was operated on after relearning the pattern discrimination; animal T_2 after the second pre-operative parametric run, and T_4 as soon as the first pre-operative run was completed. Animal T_3 died following surgery, having completed one pre-operative parametric run and learnt the pattern discrimination.

First post-operative parametric run. Fourteen days were allowed for post-operative recovery and then all three surviving animals were tested on the first post-operative parametric run. The procedure was the same as for the pre-operative runs (no initial post-operative training to criterion), except that animals T_1 and T_4 required some help during the first session of step 1, but not thereafter. This help consisted in operating the lever not more than 20 times in all from outside the box during periods of higher luminance.

Post-operative retention of pattern discrimination. Animal T_1 was retrained on the pattern discrimination after competing the first post-operative parametric run.

Post-operative criterion training. Animals T_2 and T_4 were retrained to criterion on the successive overall brightness discrimination after completion of the first post-operative parametric run. The luminance levels and double criterion were the same as required immediately before the first pre-operative parametric run. This phase lasted 3–4 days.

Second post-operative parametric run. Immediately after attaining criterion animals T_2 and T_4 were tested on the second post-operative parametric run. The procedure was the same as on previous runs.

Initial post-operative learning of pattern discrimination. Animal T_4 was taught the pattern discrimination when the second post-operative parametric run had been completed.

Results for Experiment 1

In Table I are presented the thresholds attained by the animals on the successive overall brightness discrimination. It will be seen that the four animals failed to meet the double criterion on the first pre-operative parametric run when the difference in luminance between the positive and negative cues fell to within 8·8–2·2 per cent. of the luminance of the constant (positive) cue. Both pre-operative retest values (animals T_1 and T_2) fall within the same range although the terminal threshold of animal T_2 is improved. Following operation, the three values for the first and the

two thresholds for the second post-operative parametric run still fall within the pre-operative range. However, two of the three thresholds on the first post-operative run (animals T_2 and T_4) are raised by comparison with the last preceding pre-operative values for the same animals.

More detailed results for the same test are shown graphically in Figure 2 for animals T_1, T_2 and T_4. Along the abscissa in each graph are plotted steps representing decreasing differences in luminance between the variable (negative) and constant (positive) cues. The values of these differences, expressed as percentages of the luminance of the constant cue, have already been given above for each step. A logarithmic transformation of the most suitable measure of performance is plotted along the ordinate in each graph. This measure is the ratio of the rate of lever pressing (per unit time) during the 16 min. total exposure time of the positive cue on 4 days to the rate of pressing (per unit time) during the 224 min. total exposure time of the negative cue on 4 days. A proportional measure was made necessary by the tendency of some animals to maintain a high rate of pressing even during exposure of the negative cue on the more difficult steps of a parametric run. The logarithmic transformation improves the distribution of the ratio values. The range of pre-operative performance by all four animals is indicated (by shading) on each graph, in addition to the individual scores on all runs of each surviving animal.

Performance during the second pre-operative parametric run is found to be partly inferior in the case of animal T_1 and consistently inferior in the case of animal T_2 to performance on the first pre-operative run. Animal T_2 graduated from step 5 to step 6 on the second run not because its performance was more highly differentiated in respect of the exposure of positive and negative cues than on the first run; rather, the total number of lever presses was increased to 2,569 as against 320 on the first run, and accordingly the number of rewards to 53 as against 10, so that criterion (*a*) (at least 40 rewards on any step) was achieved. It is also noteworthy that the scores on the second post-operative run of animal T_2 (but not of T_4) are again consistently worse than on the first post-operative run. There is then some evidence for progressively deteriorating performance on successive runs even with a constant neurological status.

In comparing the pre-operative with the post-operative ratios, all post-operative scores (excepting only those of animal T_1 on step 1 and of animal T_2 on step 2) are found to fall within the pre-operative range of performance. Only in the case of animal T_4 is the first post-operative run consistently inferior to the preceding pre-operative run. However, not even in this instance can the deteriorated performance be confidently atrributed to the changed neurological status. For only on step 4 is the initial post-operative performance decrement of animal T_4 greater than the deterioration occurring in the case of animal T_2 on the second of two *pre-operative* runs. Moreover the ratio for the second post-operative run of animal T_4 is higher on step 4 than on the pre-operative run. It may therefore be concluded that the three temporal operates are not reliably impaired as compared with pre-test performance at successive brightness discrimination under the conditions of testing of Experiment 1.

Reference must be made to animal T_5 of Experiment 2 in considering the performance of animals T_1 and T_4 on the pattern discrimination. From Tables I and II it will be seen that the range of trials to criterion for the pre-operative learning of this test by the three relatively experienced animals T_1, T_3 and T_5 is 150–280 trials. The post-operative learning score (510 trials) of the equally sophisticated animal T_4 therefore falls well outside the relevant control range (and barely overlaps with the range of 200–510 trials established by the author for six other unoperated and naive animals

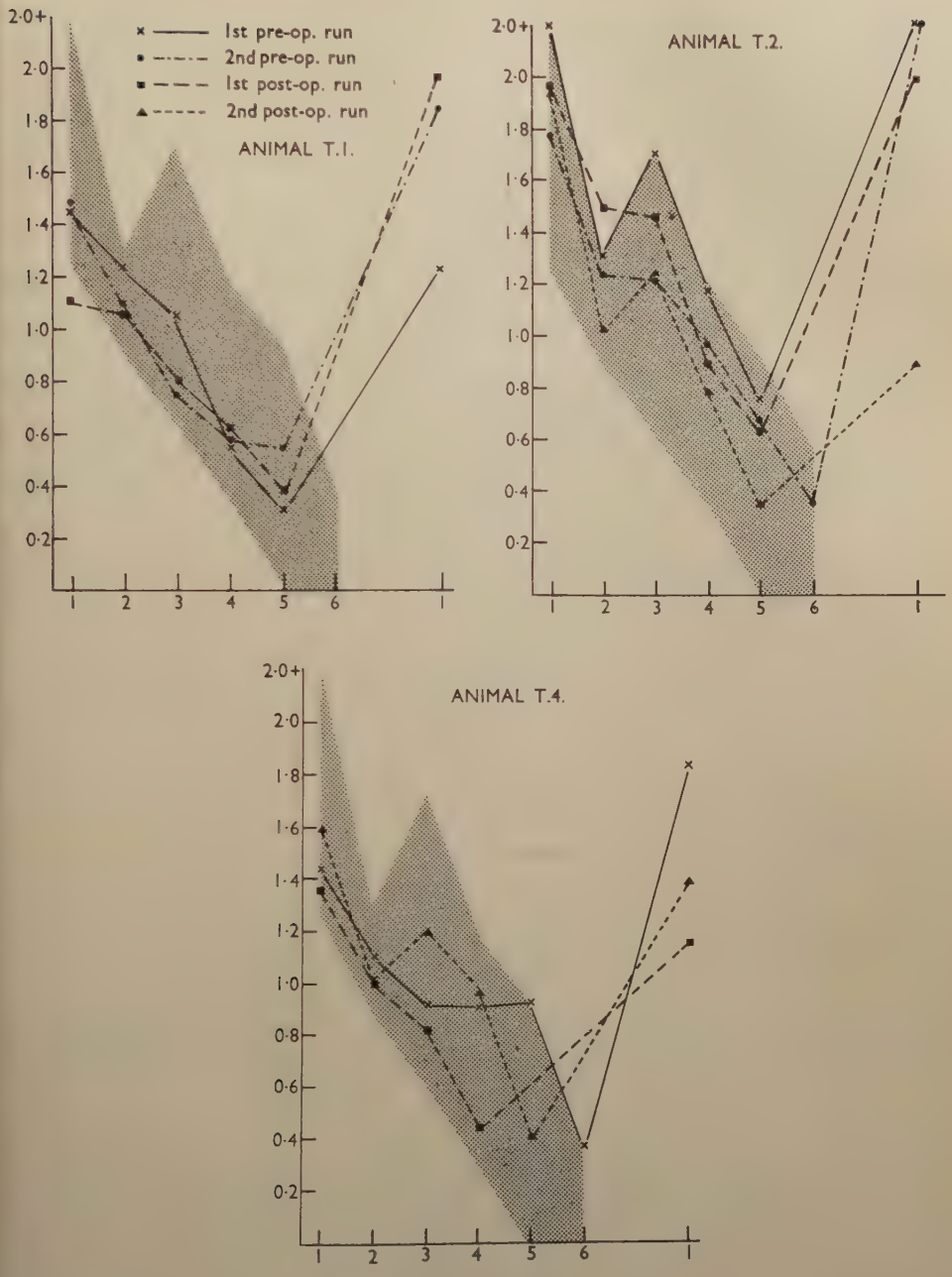

FIGURE 2

Pre- and post-operative performance scores for animals T_1, T_2 and T_4. Steps, representing geometrically decreasing differences in luminance between the positive and negative cues, are plotted along the abscissa. The logarithm of the ratio of the rate of responding during exposure of the positive cue to the rate during exposure of the negative cue is plotted along the ordinate. The range of pre-operative performance by all four animals (T_1–T_4) is indicated by shading.

on the same discrimination). Both animals T_1 and T_5 relearnt the pattern discrimination in 0 trials pre-operatively (i.e. 10 or less errors in the first 100 trials). Animal T_1 was therefore unequivocally (although mildly) impaired following surgery in view of the 190 trials required to regain criterion. Both of the animals (T_1 and T_4) tested on the simultaneous pattern discrimination thus gave evidence of post-operative impairment on this test, whereas they scored within the pre-operative range on the successive overall brightness discrimination.

TABLE I

Training Procedure and Results for Experiment I.

Animals	T_1	T_2	T_3	T_4
	Pre-operative criterion training			
First pre-operative parametric run (minimum luminance difference discriminated) ..	4·4%	4·4%	8·8%	2·2%
Pre-operative learning of pattern discrimination (trials to criterion)	250 (14 days)	— (14 days)	280	—
Second pre-operative parametric run	4·4%	2·2%	—	—
Pre-operative retention of pattern discimination	0	—	—	—
	Operation (14 days)			
First post-operative parametric run	4·4%	4·4%	Died	8·8%
Post-operative retention of pattern discrimination	190	—		—
	Post-operative criterion training			
Second post-operative parametric run ..		4·4%		4·4%
Post-operative learning of pattern discrimination				510

— Indicates that this stage of training was omitted, so that the animal at once progressed to the next stage except where 14 days' rest intervened.

Experiment 2

Training procedure (*see Table II*)

Pre-operative criterion training. Animals T_5 and T_6 were first trained to criterion (in the same apparatus as for Experiment I) on a successive brightness discrimination where a homogeneous field and an incremental disc of light superimposed upon the field served as alternative cues. Five to six sessions lasting an hour were given each week. The luminance of the globe was 10 foot candles, $\pm$ 2 per cent. For 30 trials of 8 sec. duration, spaced at random within each session, a disc of light measuring $\frac{9}{32}$ in. in diameter was projected on to the globe at a height of $10\frac{1}{2}$ in. vertically above the lever. The luminance of the disc was calculated to be 75·1 foot candles on the interior surface of the globe. If the animal pressed the lever 5 or more times during such an 8 sec. period of incremental stimulation it was rewarded with one 0·5 gm. pellet of chow. Criterion performance consisted in (*a*) obtaining at least 60 out of a maximum of 90 possible rewards on three successive test days, *and* (*b*) pressing the lever below an average rate of 12 times per min. during the periods of homogeneous field illumination on three successive days. This phase of training lasted 4–5 months.

First pre-operative incremental cue sampling. After achieving criterion the test conditions remained unchanged for both animals during the following 4 days. This 4 day period was thought to provide a representative sample of initial post-criterion performance on this test.

Pre-operative learning of pattern discrimination. Animal T_5 was then taught the pattern discrimination under the same conditions as in Experiment I.

Second pre-operative cue sampling. An interval of 14 days' rest was allowed to animal T_5 after learning the pattern discrimination and to T_6 after the first sampling period. Both animals were then given a further 4 day sampling period. The test conditions remained the same as for pre-operative criterion training.

Pre-operative retention of pattern discrimination. Animal T_5 was retrained on the pattern discrimination after completing the second pre-operative sampling period.

Operations. Animal T_5 came to operation at once after relearning the pattern discrimination, and T_6 after the second pre-operative sampling period.

First post-operative incremental cue sampling. When 14 days had elapsed to allow for recovery from the immediate effects of surgery both animals were tested in the globe for 4 days under the conditions used for pre-operative criterion training.

Post-operative retention of pattern discrimination. Animal T_5 was retrained on the pattern discrimination after completing the first post-operative sampling period.

Post-operative criterion training. Following retraining on the pattern discrimination animal T_5 was retrained to criterion on the incremental brightness discrimination under the conditions of pre-operative criterion training. This animal required 4 days to meet the criterion. Animal T_6 failed to re-attain the criterion under the same test conditions within 30 sessions.

Second post-operative incremental cue sampling. A final 4 day sample of performance was taken for animal T_5 as soon as it had attained the criterion. Sessions 26–30 of the post-operative period of criterion training were counted as an equivalent sampling period for animal T_6 (although T_6 had failed to meet the criterion).

TABLE II

TRAINING PROCEDURE AND RESULTS FOR EXPERIMENT II

Animals	T_5	T_6
	Pre-operative criterion training	
First pre-operative incremental cue sampling (ratio of response rates to positive and negative cues) ..	6·26	5·28
Pre-operative learning of pattern discrimination (trials to criterion)	150 (14 days)	— (14 days)
Second pre-operative incremental cue sampling ..	5·06	4·94
Pre-operative retention of pattern discrimination ..	0	—
	OPERATION (14 days)	
First post-operative incremental cue sampling ..	5·36	3·01
Post-operative retention of pattern discrimination	210	—
	Post-operative criterion training	
Second post-operative incremental cue sampling ..	5·46	2·18

The symbol — has the same meaning as in Table I.

Results for Experiment 2

In Table II are presented the ratios of the rate of lever pressing during the 16 min. total exposure time of the incremental light disc (positive cue) on 4 days to the rate of pressing during the 224 min. total exposure time of the homogeneous field (negative cue) on 4 days. It is noteworthy that the second pre-operative sample is inferior to the first for both animals.

Animal T_5 gives evidence of improved performance following surgery relative to both its second pre-operative sample and to the two pre-operative samples of animal T_6. On the other hand the performance of animal T_6 declines progressively with continued testing from the level attained during pre-operative criterion training. Thus both pre- and post-operatively the second sample is inferior to the first, so that the decrement apparent on the first post-operative sample cannot be attributed to the surgical procedures with any certainty. Neither temporal operate is therefore unequivocally impaired as a result of surgery on the successive brightness discrimination requiring selective response to an incremental light exposure. On the other hand animal T_5 shows no saving in relearning the pattern discrimination post-operatively.

Discussion

In what way then does the dissociation between the performance of operated monkeys on the present two forms of successive brightness discrimination (no deficit) and on the simultaneous pattern discrimination (deficit) clarify the nature of the defect following bilateral inferior temporal lesions? Taking the impairment of simultaneous pattern discrimination first, the apparent mildness of the post-operative deficit is the only unexpected feature. However, when the mean of the learning scores (227 trials) and their range (150–280 trials) for the present three animals is compared with the mean (358 trials) and range (200–510 trials) for six other unoperated animals trained by the author on the same discrimination but without prior testing in the globe, it is seen that previous experience with the successive brightness discrimination has markedly improved the pre-operative performance on the pattern discrimination. The post-operative deficits on this test cannot therefore be expected to be as severe as in naive animals (cf. Mishkin and Hall, 1955, for scores similar to those of T_4 on initial post-operative pattern learning following size discrimination; and Pribram and Mishkin, 1955, for perfect post-operative retention on a simultaneous pattern discrimination following successive presentation of the same cues).

Turning now to the tests of brightness discrimination, it is true that neither Klüver (1937) nor Settlage (1939) found any loss of capacity to discriminate brightness differences in monkeys with unilateral or bilateral occipital lesions when some loss might have been expected. On the other hand Mishkin and Pribram (1954) using cues differing in reflectivity rather than luminance and the simultaneous two-choice procedure reported defective brightness discrimination after bilateral temporal lesions in baboons. Wegener (unpublished observations) has found a similar impairment in monkeys following bilateral ablation of the temporo-parieto-preoccipital region. In his study the alternative cues (either light sources or illuminated surfaces) were presented successively in one test, simultaneously in another. According to the criterion of number of sessions required for learning as well as by other standards both forms of the brightness discrimination were considerably more difficult for all animals than was the pattern discrimination. Moreover on all runs animals graduated to progressively smaller luminance difference (which could be diminished to as little as 1·1 per cent.) until the discrimination became so difficult that their efficiency was reduced. Therefore successful performance on the brightness discrimination by the

temporal operates cannot be plausibly related to either the specific character of the alternative cues nor to insufficient test difficulty.

In evaluating the rôle of differences in cue presentation and response availability it is of importance that Pribram and Mishkin (1955) reported temporal operates to be at least as severely impaired on a successive as on a simultaneous pattern discrimination. The sequential presentation of positive and negative cues in the present study cannot therefore be critical for successful post-operative performance. It is true that in Experiment 1 changes in the "ground" (as used in Gestalt terminology) served as cues for differential responding, whereas in previous studies leading to impaired performance, as well as in the present pattern discrimination, the alternative cues were "figures" set against a ground (of greater or lesser complexity). Nevertheless the temporal lobe defect cannot be related exclusively to "figure" differentiation. For the positive cue in Experiment 2 (in which temporal removals were not followed by impairment) was a disc of light superimposed upon a homogeneous ground.

Is the availability to the animal of a single manipulandum throughout a whole test session the aspect of the test conditions leading to successful post-operative performance at brightness discrimination? In the successive discrimination of Pribram and Mishkin (1955) the formal response ("go and open food cup") was required of the animal whenever the positive cue was presented. This response was not available to the animal in between trials. If it was made in the presence of the negative cue no further reward was forthcoming (i.e. the positive cue was withheld) until the animal ceased responding in this manner on one of successive presentations of the negative cue (re-run correction technique). This procedure served to restrict the formal correct response to trials in which the positive cue was visible. In the present study, however, the animal was in no way penalized for pressing the lever during the long exposure periods of the negative cue. This kind of test situation has been recently discussed by Weiskrantz (1957). Lacking any penalty, most animals progressively increased their rate of lever pressing during the exposure of the negative cue, and this accounts for the deterioration of performance on successive runs and samples. At the same time it might appear that bilateral ablation of the inferior temporal region failed to disrupt a visual discrimination in which the formal correct response is not sharply differentiated by the test conditions from alternative modes of behaviour. Looked at in a slightly different way, the animal had less need to remember before and after operation what responses *not* to make in relation to given cues than in the more traditional forms of discrimination. In the pattern discrimination the animal was, of course, penalized by lack of reward if it made the otherwise correct formal response ("remove lid") in relation to the negative cue.

On the other hand it can be argued (Weiskrantz, personal communication) that the good post-operative brightness discrimination by the temporal operates is the result of prolonged pre-operative training. This view derives support from the recent findings of Chow and Orbach (1957) and of Orbach and Fantz (1958). These latter authors have shown that pre-operative overtraining on an easy discrimination eliminates the impairment that follows temporal ablations in the absence of overtraining. However, the results of Pribram and Mishkin (1955), Mishkin and Hall (1955) and of Pasik *et al* (1957) are at variance with this interpretation. For considerable pre- or post-operative experience of a discrimination served in these studies to abolish the post-operative impairment of temporal animals only on the easy but not on the difficult forms of the tests.

The present results, if confirmed by repetition, would then tend to suggest that the demonstration of a visual impairment in temporal operates is limited to certain conditions of testing. It could no longer be supposed that temporal lesions directly

interfere with the visual "input" upon which discrimination behaviour is based (an interpretation rejected by Pribram and Mishkin, 1955, although still left open by their findings). For not only has a change in the "situational" variables (to use their term) affected post-operative performance in the present study out of all proportion to the difference in the cues employed in brightness and pattern discrimination; but moreover no reliable impairment has been found on the brightness discriminations despite their greater difficulty. Instead, emphasis has fallen on the test conditions relating to either the amount of pre-operative training or to response differentiation. It might be predicted, if the availability of a single manipulandum is the crucial factor, that temporal operates would be impaired under the same conditions of cue presentation as used in Experiment 1, providing that two levers were made available, the one serving to procure reward at a high level of ground luminance, the other at a lower level. At any rate the present results might tentatively be taken to confirm the view of Klüver (1937) that "in future studies of cortical cases it may seem worthwhile to study more thoroughly the rôle of the motor components in visual reactions."

I am greatly indebted to Dr. K. H. Pribram for placing all the facilities required for this study freely at my disposal. Dr. J. Wegener gave much of his time to participation in all the surgical procedures, and offered most valuable advice and encouragement throughout. Professor W. Blackwood generously made available assistance for the histological preparation of the brains, and Drs. J. Schwartzbaum and L. Weiskrantz gave help in the preparation of this paper.

References

Chow, K. L., and Orbach, J. (1957). Performance of visual discriminations presented tachistoscopically in monkeys with neocortical ablations. *J. comp. physiol. Psychol.*, **50**, 636.

Ettlinger, G., and Wegener, J. (1958). Somaesthetic alternation, discrimination and orientation after frontal and parietal lesions in monkeys. *Quart. J. exp. Psychol.*, **10**, 177.

Klüver, H. (1937). Certain effects of lesions of the occipital lobes in macaques. *J. Psychol.*, **4**, 383.

Mishkin, M., and Hall, M. (1955). Discrimination along a size continuum following ablation of the inferior temporal convexity in monkeys. *J. comp. physiol. Psychol.*, **48**, 97.

Mishkin, M., and Pribram, K. H. (1954). Visual discrimination performance following partial ablations of the temporal lobe: I. Ventral *vs.* lateral. *J. comp. physiol. Psychol.*, **47**, 14.

Orbach, J., and Fantz, R. L. (1958). Differential effects of temporal neo-cortical resections on overtrained and non-overtrained visual habits in monkeys. *J. comp. physiol. Psychol.*, **51**, 126.

Pasik, T., Pasik, P., Bender, M. B., and Battersby, W. S. (1957). Some stimulus factors influencing form discrimination in the monkey with bitemporal lesions. Paper read at Eastern Psychological Association, N.Y., U.S.A.

Pribram, K. H., and Mishkin, M. (1955). Simultaneous and successive visual discrimination by monkeys with inferotemporal lesions. *J. comp. physiol. Psychol.*, **48**, 198.

Settlage, P. H. (1939). The effect of occipital lesions on visually-guided behaviour in the monkey: I. Influence of the lesions on final capacities in a variety of problem situations. *J. comp. Psychol.*, **27**, 93.

Weiskrantz, L. (1957). On some psychophysical techniques employing a single manipulandum. *Brit. J. Psychol.*, **48**, 189.

SHORTER ARTICLES AND NOTES

REACTION TIMES TO AUDITORY AND VISUAL STIMULATION IN SCHIZOPHRENIC AND NORMAL SUBJECTS

BY

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An experiment carried out to determine the relation between auditory and visual reaction times suggested that when the general level of response is slow visual RTs are faster than auditory, and that the reverse is the case when the level of response is fast. Thus most normal subjects have an auditory RT faster than visual, and most schizophrenics the reverse. However, the difference between auditory and visual RTs does not appear to depend directly on schizophrenic pathology except in so far as this is a factor in the general slowness of reaction time.

Introduction

In an earlier study (Venables and Tizard, 1958) it was shown that the reaction time of schizophrenic subjects to visual stimulation was shorter than that to auditory stimulation over a range of auditory and visual stimulus intensities.

This reversal of the findings of fourteen studies of normal subjects reported by Teichner (1954) showing auditory RTs shorter than visual RTs was thought to be of sufficient interest to warrant further investigation. As Teichner (1954) points out, the question of the influence of modality on RT has not in fact been answered in any study on the literature in view of the difficulty of comparing stimuli from different modalities on the same scale.

In the present experiment the initial intention was to attempt to find an auditory and a visual stimulus intensity which would with normal subjects give equal RTs and then to compare the reactions of schizophrenics to these two stimuli. Owing, however, to limiting factors this condition could not be achieved and the stimulus intensities in fact used were the best compromise possible. While it would have been possible to make the stimulus comparison using only a manual response the opportunity was taken to use also speech response to the same stimuli.

In summary therefore the aim of this experiment is to examine the influence of auditory and visual stimulation, and manual and speech response on the reaction times of schizophrenic and normal subjects.

Method

Apparatus and Procedure

The visual stimulus intensity chosen was one which was the brightest thought to be capable of giving an optimally fast reaction time with schizophrenics in view of the finding (Venables and Tizard, 1956) of a paradoxical lengthening of RT with increased visual stimulus intensity after a point of inflexion at around 300 foot-lamberts. The intensity of the visual stimulus, a diffusely illuminated circular patch 0·75 cm. in diameter set in a 2 × 2 ft. matt black board was 320 foot-lamberts. The lowest auditory stimulus intensity which could be used was limited by the level which could be regularly discriminated from the ambient noise level by an amplifier operated voice key which was used to indicate both the onset of stimulus and response in the auditory stimulus-speech response condition. The stimulus had an intensity of 60 db. and a frequency of 500 cps. The duration of both the auditory and the visual stimuli was 200 millisec. The manual response was pressure on a telephone type key, the speech response that of saying the

nonsense syllable "bip." No forewarning was used, a new stimulus was presented once every 7.5 sec. RTs were measured in millisec. by a "dekatron" timer. The onset and duration of stimuli were controlled electronically. The maximum delay due to additional circuitry in the speech response conditions was 6 millisec. All stimulus intensities and times were kept constant by the use of a regulated voltage source supplying the apparatus.

Initially each subject made 30 consecutive responses in each condition, but as it was found that there was no difference in mean RT for the first, second and third, ten responses the majority of subjects made ten responses only to each condition with a consequent improvement in co-operation.

The four conditions: auditory stimulus-manual response (AM), auditory stimulus-speech response (AS), visual stimulus-manual response (VM) and visual stimulus-speech response (VS) were presented in the order of the row of a balanced latin square to each subject, order effects were thus eliminated over all subjects.

TABLE I

MEAN REACTION TIMES (IN 1/100 SEC.) FOR ALL SUBJECTS ON THE FOUR EXPERIMENTAL CONDITIONS

Active Paranoid Schizophrenics				*Active Non-paranoid Schizophrenics*				*Normals*			
AM	*VM*	*AS*	*VS*	*AM*	*VM*	*AS*	*VS*	*AM*	*VM*	*AS*	*VS*
19	32	23	35	32	35	68	50	19	33	34	37
20	28	37	42	36	37	57	44	19	29	31	36
26	33	49	53	38	65	55	66	20	27	31	40
31	29	49	51	42	74	58	61	20	29	35	48
31	48	51	54	51	41	64	57	21	30	27	37
33	38	33	46	51	46	79	62	22	30	27	37
33	40	66	73	67	69	71	73	23	28	30	37
40	39	57	48	70	91	79	80	23	30	31	40
40	47	68	72	86	56	57	51	23	33	32	43
62	49	55	56	90	74	118	93	24	32	43	45
63	39	51	50	93	106	59	56	25	29	28	34
95	64	59	55	107	88	165	148	25	32	30	41
								26	28	31	42
$\bar{X}$ 41·0	41·0	50·0	53·0	$\bar{X}$ 66.0	65·0	77·0	70.0	27	31	34	39
								29	35	45	45
								31	30	41	40
								39	34	38	41
								40	39	57	53
								43	37	52	45
								46	39	55	45
Withdrawn Paranoid Schizophrenics				*Withdrawn Non-paranoid Schizophrenics*							
TM	*VM*	*AS*	*VS*	*AM*	*VM*	*AS*	*VS*				
27	33	52	50	32	30	70	55	$\bar{X}$ 27·0	32·0	37·0	41·0
32	32	43	46	33	40	53	65				
34	32	53	48	39	56	49	55				
43	42	83	92	46	55	81	67				
47	39	45	57	53	75	75	61				
71	45	50	54	57	61	48	50				
71	118	96	65	60	35	57	57				
78	59	79	90	68	59	73	50				
87	37	113	71	85	59	110	76				
97	99	101	63	87	72	88	94				
101	107	101	86	89	116	116	70				
106	103	114	105	91	47	77	119				
$\bar{X}$ 66·0	62·0	77·0	69·0	$\bar{X}$ 61·0	59·0	74·0	68.0				

Subjects

Forty-eight chronic schizophrenic subjects were used who were between the ages of 22 and 56 years and had all been in hospital for two years or more. They were selected from larger populations in two hospitals to form four equal sub-groups on the basis of two dichotomies: (1) paranoid-nonparanoid using clinical diagnosis as the determinant and (2) active-withdrawn using position above and below mid-point on a rating scale (Venables, 1957) as the determinant. Analysis of variance showed that both the paranoid groups (mean age 45·0; S.D. 5·87 years) were significantly older than the nonparanoid groups (mean age 37·58; S.D. 7·83 years). There was no age difference between the active and withdrawn groups, nor was there any difference in length of stay (total mean 11·95; S.D. 10·04 years) between any of the groups.

Twenty normal subjects taken from the artisan staff from one of the hospitals also took part in the experiment. Their mean age was 40·5; S.D. 10·95 years which did not differ significantly ($t = 0{\cdot}32$) from those of the schizophrenics.

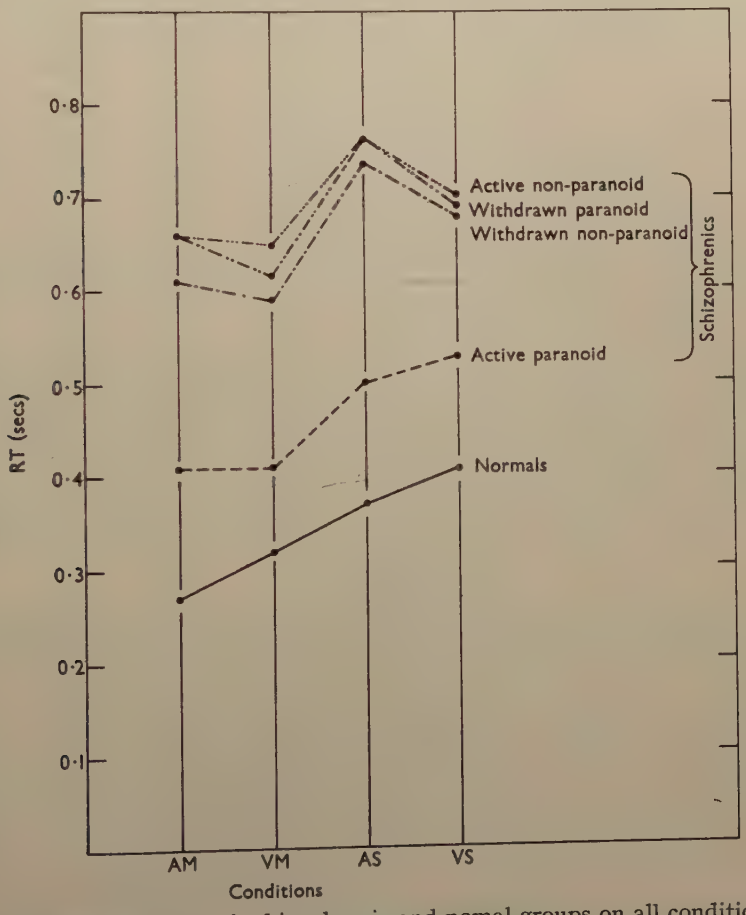
All subjects were audiometrically screened, no subject was used in the experiment who showed a hearing loss greater than 20 db. in either ear.

Results

The mean RTs for each subject in each diagnostic group; and for each of the four experimental conditions are given in Table I.

The mean RT for each group and for each condition are shown in graphic form in Figure 1.

FIGURE 1



Mean reaction times of schizophrenic and nomal groups on all conditions.

The trends within the schizophrenic groups, shown in Figure 1, were examined by an analysis of variance. This showed that active schizophrenics were faster than withdrawn ($p < 0{\cdot}001$), paranoid schizophrenics were faster than nonparanoid ($p < 0{\cdot}001$), manual responses were faster than speech ($p < 0{\cdot}001$) and visual stimuli gave rise to faster responses than auditory ($p < 0{\cdot}05$). There was a significant first order interaction term which indicated ($p < 0{\cdot}001$), as evident from Figure 1, that the active-paranoid sub-group gave rise to the substantial part of the greater speed shown by the active and paranoid factors taken separately. None of the other nine interactions were significant. In view of the difference in age between the paranoid and nonparanoid sub-groups a correlation was run between age and mean RT taken over the four conditions and it was found to be + 0·001, indicating that age was not a contributory factor to the results shown by the analysis of variance.

An additional analysis of variance of the schizophrenic data showed a significant ($p < 0{\cdot}01$) difference in mean RT between the patients from the two hospitals in which this experiment was carried out. There was, however, no significant interaction between hospitals and any other variable, indicating that the same pattern of responses was found in each.

An analysis of variance carried out on the schizophrenic and normal data showed that normals were faster than schizophrenics ($p < 0{\cdot}001$), manual responses were faster than speech ($p < 0{\cdot}001$) and that there was a significant ($p < 0{\cdot}01$) interaction term which showed that auditory responses were faster than visual in the normal group, and the reverse in the schizophrenic group. These results and further examination of Figure 1 showed that, although over the whole schizophrenic group auditory responses (mean R.T. = 0·64 sec.) were significantly ($p < 0{\cdot}05$) slower than visual (mean RT = 0·61 sec.), there appeared to be a relationship such that as the general level of responding became more slow so responses to auditory stimuli became correspondingly slower than those to visual stimuli.

The combined normal and schizophrenic groups were split at the median values for reaction times to auditory stimuli. For the auditory stimulus-manual response condition the division was at 0·39/0·40 sec. and for the auditory stimulus-speech response condition the division was at 0·55/0·56 sec.

For the subjects having AM reaction times below 0·39 sec., manual responses to auditory were shorter than responses to visual stimuli. For the subjects having AM reaction times above 0·40 sec. responses to visual stimuli were shorter than to auditory stimuli. Similarly, for subjects having AS reaction times of 0·55 sec. or shorter, speech responses to auditory were shorter than responses to visual stimuli. For the subjects having AS reaction times of 0·56 sec. or greater, responses to visual stimuli were shorter than to auditory stimuli. These results are summarized and significance levels shown in Table II.

TABLE II

DIFFERENCES IN RT TO AUDITORY AND VISUAL STIMULI IN SUBJECTS DIVIDED AT THE MEDIAN AUDITORY RT INTO FAST AND SLOW RESPONDERS

Response	*Manual*		*Speech*	
Subjects with ..	AM < 0·39 sec.	AM > 0·40 sec.	AS < 0·55 sec.	AS > 0·56 sec.
AM VM Difference	AM < VM	AM > VM	AS < VS	AS > VS
t	5·83	2·23	5·03	3·19
p	< 0·001	< 0·05	< 0·001	< 0·01

To examine whether this auditory-visual response differential was based on presence or absence of schizophrenic pathology the data were examined more closely. In the case of the normal subjects taken alone auditory-manual RTs were faster than visual-manual ($t = 3{\cdot}54$ $p < 0{\cdot}01$), and auditory-speech RTs faster than visual speech ($t = 5{\cdot}35$ $p < 0{\cdot}001$). However, in the case of the three normal subjects with AM $> 0{\cdot}40$ sec. the visual RT was in each case shorter and in the case of the same three normal subjects with AS $> 0{\cdot}55$ sec. the visual RT was similarly shorter. Conversely in the case of the 16 schizophrenic subjects with AM $< 0{\cdot}39$ sec., 12 had a longer visual RT and in the case of 17 schizophrenics with AS $< 0{\cdot}55$ sec., 14 had a longer visual RT.

There is thus suggestive evidence that this auditory-visual response differential is not confined to subjects diagnosed as schizophrenics, but is shown more often in them because their general level of response is on the whole slower than that of normal subjects. The analysis of variance of the schizophrenic data did not yield a significant interaction term, which would suggest that visual responses faster than auditory or vice versa were characteristic of any schizophrenic sub-group.

In either the analysis of the schizophrenic data alone or combined with that of the normal subjects no interaction term was found which would indicate that differences in the RT between manual and speech response could be related to any category of subject. A mean value for the difference between manual and speech responses was found to be 0·1 sec. over the total of 68 subjects.

Discussion

The findings in this experiment confirm and extend the report of Wells, Kelley and Murphy (1921), who for a group of normal subjects show "those with quicker time to sound tend towards *relatively* slower time to light." Wells and Kelley (1922) state that a group of dementia praecox patients have a smaller light-sound ratio (i.e. the percentage which light RT is of sound RT) than normal, although their figure of 108 per cent. indicates that normal RT was never shorter than auditory RT. However, with their low mean RT for auditory and visual RT combined of 0·237 sec. this would not be expected.

Extension of the findings reported must await experimental work, but in this instance at least there would seem to be evidence of a continuum in a range of performance from that exhibited by normal subjects to that of the frankly schizophrenic.

The work was carried out in Springfield and Banstead Hospitals by kind permission of the Medical Superintendents, Dr. H. C. Beccle and Dr. E. P. H. Charlton.

References

Teichner, W. H. (1954). Recent studies of simple reaction time. *Psychol. Bull.*, **51**, 128–49.

Venables, P. H. (1957). A short scale for rating "activity-withdrawal" in schizophrenics. *J. ment. Sci.*, **103**, 197–9.

Venables, P. H., and Tizard, J. (1956). Paradoxical effects in the reaction time of schizophrenics. *J. abnor. soc. Psychol.*, **53**, 220–4.

Venables, P. H., and Tizard, J. (1958). The effect of auditory stimulus intensity on the reaction time of schizophrenics. *J. ment. Sci., in press.*

Wells, F. L., Kelley, C. M., and Murphy, G. (1921). Comparative simple reactions to light-sound. *J. exp. Psychol.*, **4**, 57–62.

Wells, F. L., and Kelley, C. M. (1922). The simple reaction in psychosis. *Amer. J. Psychiat.*, **2**, 53–9.

APPARATUS

A SIMPLE TWO-CHANNEL PROGRAMMING UNIT PERMITTING THE CONTROL OF CONDITIONAL PROBABILITIES

BY

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Current research on serial information processing by the human operator has led psychologists to interest themselves in programming devices. Most experiments in this field consist of presenting the subject with series of signals at a speed approaching the limit of human capacity. It is then no longer possible for the experimenter to control the display himself while the subject is working, as is the case for instance in many discrete reaction time studies. Some sort of automatic programming device becomes necessary.

The most flexible solution is probably the punched tape programmer. But that sort of apparatus, being rather expensive, is often unavailable in psychological laboratories as yet. A more common device is the multiple position relay or uniselector. This has for many purposes the great disadvantage that, unless one uses a number of them, the same series of signals recurs after 25 or 50 steps. When, as is generally the case, the subjects need a fair amount of training on the task, the danger exists that they learn the sequence of signals.

The apparatus to be described, which is based on the use of two 50-position uniselectors, avoids this difficulty by taking blocks of signals alternately from one or the the other, so that a continuously changing series can be generated. It was designed primarily to enable the control of first order conditional probabilities among binary signals. But the principle can easily be applied to higher numbers of signals and, because of the flexibility achieved, is of interest even when the main concern is not with conditional probabilities.

The general principle of the apparatus is derived from the procedure used by one of the authors in some unpublished experiments on card sorting, to prepare packs of cards with known conditional probabilities. Suppose the cards are of two types only: black and red, and we want to build packs governed by the following matrix of conditional probabilities:

$$p_b(b) = p_r(r) = 0{\cdot}75$$
$$p_b(r) = p_r(b) = 0{\cdot}25$$

($p_b(b)$ = probability of black after black, $p_b(r)$ = probability of red after black, etc.). In other words, after each card the chances are 3/4 that the next will be of the same colour, 1/4 that it will be of the other. We prepare two piles of cards, a "red" pile with 3/4 red cards, a "black" pile with 3/4 black cards, and shuffle the cards of each pile thoroughly. We take a first card at random. If it is red, the next card to be chosen is the first one in the "red" pile. If this card is red, we go on with the next in the same pile. If it is black, we take the first card in the black pile. The rule is that the next card is always taken from the pile corresponding to the colour of the card which came last. The probability of each colour thus always depends on the

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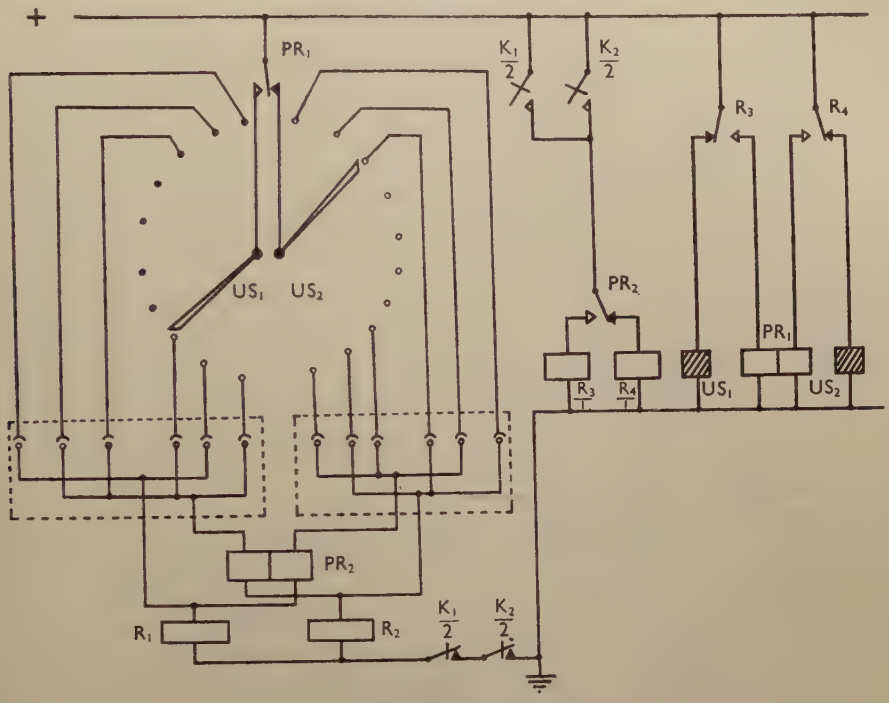
colour of the last card. To build a pack with 3 chances out of 4 that the next card is different, we put 3/4 black cards in the "red" pile and 3/4 red cards in the "black" pile.

The apparatus simulates this procedure. Instead of red *vs.* black cards, we now have the current which is fed either to relay R_1 or to relay R_2, giving a "left" or a "right" signal (causing e.g. a left or a right bulb to light up). To the two piles of cards correspond the two 50-positions uniselectors US_1 and US_2. In each position each uniselector makes the contact with one of the two signal relays. At each moment, the current is sent through one US, depending on which signal occurred last: through "left" uniselector US_1 after a left signal, through US_2 after a right signal. After each signal, the US through which the current will be sent next proceeds one step.

FIGURE 1



Basic circuitry.

The probability of a left signal after left is equal to the proportion of left connections on US_1, since after left the next signal is always taken on that US, and the same for the probability of right after right. To be able to vary these conditional probabilities the connections of the US contacts to the two signal channels are made through removable 50-pins plug-in sockets. The "meaning" of each US position thus depends on the wiring of the socket which is used. One can readily modify the statistical properties of the series of signals by replacing the sockets with others wired in a different manner.

The basic circuitry is represented on Figure 1. The apparatus is designed to provide a self-paced task: it is the subject's response which causes the disappearance of the signal and brings the apparatus into a new position. This feature, however, is not fundamental and it would make no great difference in the circuitry if both

effects had to depend on some external signal, as in a forced paced task. The uniselectors indicated are 25-position multiple-bank ones modified so as to give runs of 50 signals before repeating themselves.

The subject responds by pressing one of two keys, K_1 and K_2, each of them having one make and one break contact.

The current is fed through the contacts of US_1 (the "left" US) or of US_2 ("right" US) according to the position of the side-stable polarized relay PR_1. From US_1 to R_1 and from US_2 to R_2, the connection is direct. But the "crossed" channels US_1–R_2 and US_2–R_1 pass through the coils of the side-stable polarized relay PR_2. PR_2 works as a *memory*. Its position is left or right according to whether the last signal was left or right. Whenever a right signal occurs on the left uniselector US_1, the current is sent through the right coil of PR_2. Being side-stable this will stay in that position, even after the current is interrupted, until a left signal on US_2 has the reverse effect.

TABLE I

Typical Sequence of Events

		US Position		*US Coil*								
No.	PR_1	US_1	US_2	US_1	US_2	R_1	R_2	K_1	K_2	PR_2	R_3	R_4
1	L	3	12	+	+	+	−	−	−	L	−	−
1′	L	4	12	−	+	−	−	+	−	L	+	−
2	L	4	12	+	+	−	+	−	−	R	−	−
2′	R	4	13	+	−	−	−	−	+	R	−	+
3	R	4	13	+	+	−	+	−	−	R	−	−
3′	R	4	14	+	−	−	−	+	−	R	−	+
4	R	4	14	+	+	+	−	−	−	L	−	−
4′	L	5	14	−	+	−	−	+	−	L	+	−

Meanings of symbols:

for PR_1 and PR_2, L = contact to the left; R = contact to the right.
for R_1, R_2, R_3, R_4 and the coils of US_1 and US_2: + means: energized; − means: de-energized.
for K_1 and K_2: + means pressed.

Events to which the example corresponds:

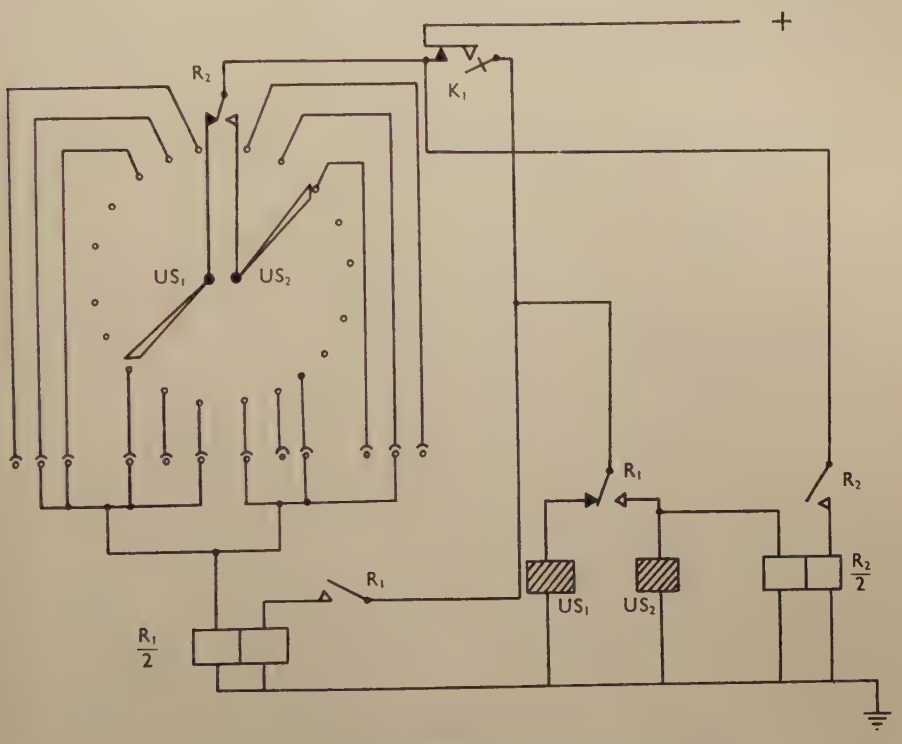
1: left signal from left US.
1′: correct response.
2: right signal from right US.
2′: correct response.
3: right signal from right US.
3′: incorrect response.
4: left signal from right US.
4′: correct response.

When one of the response keys is pressed, the signal relay is de-energized and, at the same time, either R_3 or R_4 is energized according to whether PR_2 is in the left or the right position. Thus R_3+ means: response to a left signal, and R_4+: response to a right signal. R_3 and R_4 have two functions: they control the position of the other side-stable polarized relay PR_1, and they interrupt the current on the US coils (USs proceed on a break). When R_3 is energized, PR_1 is brought to the left position, if it was not yet in that position, and US_1 is pushed one step ahead.

The operation of the different elements is exemplified for a few typical cycles in Table I. As will be noted, when a signal implying that the other US will be used next occurs, the change is operated in two steps: at the moment the new signal occurs, the position of PR_2 changes; at the moment of the response to this signal, the position of PR_1 is changed.

Special care must be given to the preparation of the basic series, wired on the programme sockets. The apparatus takes alternately one block of left signals plus one right signal from US left, then one block of right signals plus one left signal from US right, etc. (this is true only if the "blocks" referred to can be of length 0). Thus, the number of times the apparatus jumps from US_1 to US_2 in one revolution of US_1 is equal to the number of right signals on the left socket, and conversely for the jumps US_2–US_1. If the numbers of jumps in both directions are equal, the same series recurs after 100 steps. But if they differ by 1, it does not do so before thousands of steps.

FIGURE 2



Alternative circuit suggested by Mr. M. P. Atkinson.

Another point of importance is the fact that the series is composed of the blocks wired on the sockets. Although the order of these blocks is continuously changed, the overall frequency of each block length (n) will depend completely on the frequency of blocks of length n–1 on the programme sockets. If the wiring of the programme sockets is decided from a table of random numbers, any chance deviation from the population parameters will be replicated all the time the same sockets are used. In our opinion, the best solution is to build the basic series so that the relative frequency of each block length deviates as little as possible from its expected probability. Of course, the series will always be more stationary than a true random series. This is the main limitation of the principle described.

Thanks are due to Dr. J. A. Leonard, who contributed many valuable suggestions and whose "five choice test" was the main starting point for the design of this apparatus.

Note. Mr. M. P. Atkinson, of the Control Mechanisms and Electronics Division, National Physical Laboratory, has suggested the alternative circuit appearing on Figure 2. This one uses only one ordinary and two double-coiled relays. (As Mr. Atkinson writes, "K_1 might be a relay which is operated by either of the two keys in the original circuit.") The current for the signal bulbs would in this case pass through a further break contact of K_1 and be fed to the left or right bulb through change-over contacts of R_2. For the functions indicated in the paper, Mr. Atkinson's solution is clearly more elegant. When the automatic counting of error must be provided, as will nearly always be the case, a further relay will, however, be needed to memorize which signal came last. In our circuit, an error is indicated by the combinations $K_1 + R_4 +$ and $K_2 + R_3 +$.

EXPERIMENTAL PSYCHOLOGY SOCIETY

Rules

Name and Objects

1. The Society shall be called "The Experimental Psychology Society."

2. The Objects of the Society shall be the furtherance of scientific enquiry within the field of Psychology and cognate subjects, by holding periodical meetings at which papers may be read and discussions held, and by such other activities as may be decided upon by the Society, and the dissemination of information and educational material made available as a consequence of psychological research including the publication of *The Quarterly Journal of Experimental Psychology*. The Society shall not engage in any activity intended to affect the professional status of its members or of psychologists generally.

Members

3. Membership is open to persons of sufficient scientific standing, ability and continuing interest in the field defined in Rule 2, namely the field of scientific enquiry in psychology and cognate subjects as interpreted by the Society in accordance with these Rules.

4. The members shall consist of Ordinary Members, Honorary Members, and Visiting Foreign Members, admission to any class being subject to the principle stated in Rule 3 and all classes being subject to the relevant provisions of Rule 29.

5. Honorary and Visiting Foreign Membership shall be by invitation only. Honorary Membership may be granted to persons (British or Foreign) of outstanding eminence and seniority. Visiting Foreign Membership may be granted, for a period not exceeding one year, to persons (British or Foreign) meeting the requirements of Rule 3 and working temporarily in Britain, and such persons shall be re-eligible for one further year only.

(*a*) The total number of Honorary Members at any one time shall not exceed eight. The number of Visiting Foreign Members shall be free of any limit, total or differential, unless and until any such limit is imposed by the procedure of Rule 9 (but determined independently of any limit respecting Ordinary Membership).

(*b*) Except as otherwise stated herein, election to either class shall conform to the relevant provisions of Rules 6, 7, 8, 9 and 10, and shall require the same proportion of support under Rule 10 as, prior to the said election, is in force for Ordinary Membership.

(*c*) Election to Visiting Foreign Membership may take place at any General Meeting, by show of hands. Honorary Members shall be elected only by secret ballot at an Annual General Meeting. No person shall be presented for election to either class without the Committee's approval.

(*d*) Honorary and Visiting Foreign Members shall not be liable to pay any subscription, shall not be present during the transaction of business except at the Committee's invitation, and shall not have power to vote. They shall, on the same terms and conditions as Ordinary Members, be entitled to attend all scientific sessions, to receive any publications issued by the Society, and to subscribe to *The Quarterly Journal of Experimental Psychology* at the rates applicable to Ordinary Members.

Admission to Ordinary Membership

6. Each Candidate shall be proposed by one Ordinary Member and seconded by at least one and not more than three Ordinary Members. The names of the Candidate, the Proposer and the Seconder(s), together with a statement of the Candidate's qualifications, experience, present work and interests, shall be submitted to the Committee not less than three months before the next Annual General Meeting. The Committee shall, not less than two months before the said Meeting, select those Candidates whom it considers eligible. The names thus selected shall be presented, with an indication of the Committee's approval attached, for election at the said Meeting.

A Candidate not thus selected shall be informed (if possible through his/her Proposer) and shall nevertheless be entitled, if again proposed and seconded (not necessarily by the same persons as before) to be presented for election at the said Meeting.

7. A list of all Candidates to be presented for election at a given Annual General Meeting, together with such relevant information as the Committee may decide, shall accompany the Notice of the said Meeting, such list and information being supplied to Ordinary Members only.

8. Election to Ordinary Membership shall take place only at an Annual General Meeting and shall be by secret ballot of Ordinary Members only. Votes delivered by post or by hand shall be accepted if received by the Secretary when (or before) called for at the said Meeting by the Chairman.

9. An Annual or Extraordinary General Meeting previous to the Meeting at which the election is held shall determine what upper limit, if any, is to be placed on the number of Candidates elected and what proportion of support is to be required under Rule 10. Each Ordinary Member shall be entitled to cast one vote per Candidate.

10. Candidates shall be elected in the order of their numerical support until either all the vacancies (if limited under Rule 9) have been filled or no Candidate is supported by at least such a proportion of the Ordinary Members as has been determined according to Rule 9.

Officers and Committee

11. The business of the Society shall be conducted by a Committee consisting of the President, Secretary, Treasurer, Editor and seven other members, and it shall have power to co-opt two further members. All members of the Committee shall be chosen from Ordinary Members of the Society.

Election of Officers and of Members of the Committee and the Editorial Board

12. The President shall be elected for one year from among the Ordinary Members by the Annual General Meeting. He/she shall be re-eligible for the succeeding year, but shall then retire and shall not again be elected (but may be co-opted) to the Committee for a period of not more than one year.

13. The Secretary and Treasurer shall be appointed by the Committee from among its members. They shall hold office for one year and shall always be re-eligible to the Committee. In addition, the Committee may, at the request of the Secretary, appoint at any time from among its members an Assistant (or otherwise designated) Secretary, who shall retire and be eligible for re-election at the same time and under the same provisions as the Secretary. The powers and duties of any such Assistant Secretary shall be as decided from time to time by the Committee, subject to the Secretary's approval, and may be such as to require that the word "Secretary" in Rule 11 be deemed to include the said Assistant Secretary.

14. Ordinary members of the Committee (other than the Officers) shall be elected by the Annual General Meeting for one year and shall be re-eligible for the succeeding year at the end of which they shall not (unless they then occupy the position of Secretary, Assistant Secretary or Treasurer) again become eligible to the Committee for a period of two years.

15. Co-opted members of the Committee shall hold office until the next Annual General Meeting, when they shall be eligible for election as ordinary members or for co-option again.

16. The Editor shall be elected by an Annual or Extraordinary General Meeting for a period of four years and shall be re-eligible for a further period of four years, but shall thereafter be ineligible for a period of four years.

17. The Editorial Board shall consist of the Editor and of not less than ten and not more than sixteen other members. The said other members shall be appointed by the Committee, having regard to the advice of the Editor, and may be re-appointed for not more than two further successive periods of four years. Any such other member who has served continuously for twelve years shall thereupon retire and shall not again be appointed until four years have elapsed.

18. Nominations for membership of the Committee shall be received by the Secretary at least four weeks before the Annual General Meeting. Such nominations may be made by any Ordinary Member or by the Committee, and a list of such nominees and of their nominators shall accompany the Notice of the said General Meeting which shall be delivered to all (and only) Ordinary Members at least fourteen days before the said General Meeting.

Subscription and Finance

19. Each Ordinary Member shall pay an annual subscription of two pounds, which shall entitle him/her to attend all Meetings (Scientific and General) of the Society and to receive (except as may otherwise be decided by the Committee) any publication issued by the Society. *The Quarterly Journal of Experimental Psychology* shall be sent free of cost to all Members whose subscriptions have been paid. Subscriptions are payable in advance and are due on 1st January in each year. If a subscription has not been paid by 1st April in any year, the Treasurer shall notify the Member concerned; and if, after a further reasonable period, the subscription remains unpaid, the Treasurer shall report to the Committee, which may take action under Rule 29.

Meetings

20. General Meetings of the Society shall be designated Annual, Ordinary or Extraordinary. Annual and Ordinary General Meetings shall be held at such times and places as may be determined by the Committee, but in each year there shall be at least two General Meetings other than the Annual General Meeting. Scientific Meetings shall be organized by the Committee or by someone authorized by the Committee to act on its behalf.

21. The Annual General Meeting shall be held in December of each year or in January of the following year (or, in case of necessity, at such other time as the Committee may determine). At the said Meeting the Secretary shall present a Report and the Treasurer shall present a Financial Statement.

22. At least 14 days' written notice of all General Meetings shall be given to all Ordinary Members and to such other Members as may, pursuant to Rule 5, be invited to attend.

23. The President shall take the Chair at any General Meeting, or, in the absence of the President any member of the Committee may be chosen by the Committee or by the General Meeting to preside. In the absence of the Secretary, the Committee or the General Meeting shall appoint an acting Secretary for the duration of the said Meeting. The quorum for any General Meeting shall be one-quarter of the current Ordinary Membership.

24. An Extraordinary General Meeting may be summoned at any time by the Committee or (on a written requisition signed by at least ten Ordinary Members) by the Secretary. The Notice convening the Meeting (or, in the latter event, both the Requisition and the Notice) shall specify the resolution or resolutions to be moved thereat and no business other than that arising out of the resolution(s) so specified shall be dealt with or transacted at such Meeting.

25. Except as otherwise provided or implied by these Rules or by subsequent Resolution or by decision of the Committee or (in case of necessity) by a ruling of the Chairman, a motion (duly seconded and in order) shall be voted upon by show of hands and carried by a simple majority of those present and voting. In the event of an indeterminate result, the Chairman may declare it null and void and refer the motion for futher discussion and/or reformulation, or may exercise an additional or casting vote.

Committee Meetings and Procedure

26. The Committee shall decide at what times and places it shall meet. In the absence of the President it shall choose a Chairman from among its members. Seven members, including the Secretary (or acting Secretary) shall constitute a quorum.

Visitors

27. Each Ordinary Member may introduce one visitor to the scientific sessions associated with any General Meeting. The Committee may introduce visitors, and such guests of the Committee may be invited to make scientific communications to the Society. The names of visitors and of Members introducing them shall be entered in a book provided for the purpose. Visitors shall not be present during the transaction of business except at the invitation of the Committee, and in no circumstances shall have power to vote.

Alteration of Rules

28. These Rules may be altered, revoked, amended or added to in any manner and to any extent at the Annual General Meeting or at any Extraordinary General Meeting specially convened for that purpose but notice of the proposed alteration shall be given in the Notice convening the Meeting and any such alteration shall require a two-thirds majority of those present and voting thereon.

Resignation and Expulsion

29. Any Member of the Society may by written notice signed by himself and addressed to the Secretary at least one calendar month before his/her subscription becomes due and on payment of all arrears of subscriptions payable by him/her retire from Membership of the Society and the Committee shall have power pursuant to a resolution passed at any Annual or Extraordinary General Meeting of the Society to require the resignation of any Member without assigning any reason for so doing or in default of such resignation to expel such Member from the Society but in the latter case only after affording such Member an opportunity of being heard by the Committee on the subject of his/her expulsion from the Society before resolving on such expulsion.

BOOK REVIEWS

A Textbook of Psychology. By D. O. Hebb. London: W. B. Saunders, Co. 1958. Pp. 276. 31s. 6d.

It is my belief that any textbook should be judged in relation to the author's aims. Hebb's intentions are threefold: to present sufficient information and as many ideas as will allow the introductory student to understand psychological problems, to foster a rigorously scientific approach to a subject in which it has too often been absent, and finally to further an interest in psychology going beyond the first brief course.

This accounts for the relative brevity of the book. Many customary topics like psychophysics are omitted since they have been adequately described elsewhere. Others like psychopathology are surely absent because they cannot be fully and rigorously expounded in only a part of a book. But such topics which remain are considered from a point of view which should interest all students even if they cannot subscribe to it. Concepts like "set" and "arousal" are not only used to explain something else for this simply alters the focus of the problem. Instead they are themselves subjected to a searching theoretical consideration and it is Hebb's forte to ask what these phenomena must involve in the brain.

This necessitates a certain amount of knowledge of the structure and function of the nervous system and several of the early chapters are devoted to this. It is pleasing to find a clear description of the pyramidal system, the third ventricle, and the diecephalon; for these and similar terms are seldom defined in psychology. Hypothetical neural organization is fairly evenly mixed with accepted facts and fortunately the author is at pains to emphasize this at the outset. However, the difficulty still remains of distinguishing a legitimate inference from a flight of fancy, or a new idea from an old one which is disguised in a new terminology. Not everyone will be satisfied that interaction of cell assemblies is more explanatory than association of ideas.

Considerable space is devoted to the related phenomena of "set" and "attention" but unless Hebb somewhere introduces the concepts of inhibition and fatigue then it is difficult to see how he can account for all aspects of attention. For Hebb a novel stimulus only captures attention if it is very intense or already commands "strongly established central processes" with a low limen for firing. But this is manifestly not so during deterioration of performance at vigilance tasks which occurs despite efforts to concentrate. This inadequacy of a hypothetical neural model may explain why many people prefer to shun physiological terms completely and talk instead in the language of cybernetics. If Hebb believes that his approach is more desirable, and many will sympathise with him, then he must at least leave no doubt that it can explain behaviour more satisfactorily.

Hebb presents a very fair account of various views of reinforcement and offers one of his own in which reinforcement consists of a change in the amount of total cortical activity. If the latter is at a high level, facilitation and interaction of phase sequences is so great that no single phase sequence can gain precedence; an event which reduces the cerebral chaos permits a more stable condition of central nervous activity which tends towards the continuation of the phase sequence correlated with that event. Hence it is learnt. If, on the other hand, the level of arousal is low then cortical transmission will be poor and those events will be learnt which raise it to a level where a phase sequence can have some duration in time. We now see that reinforcement may involve drive induction (which might explain latent learning), as well as drive reduction and the latter will only be reinforcing when drive is already at a high level.

At intervals throughout the book comparisons are drawn between the behaviour of animals and man which are too loose to be comfortable, for instance, the suggested homology between human misers and chimpanzees which collect food tokens. The overt behaviour may appear similar but are the intentions? However, to stress the possible shortcomings of this book would be both captious and misleading. The section on maturation, heredity and learning is full of common sense and demolishes some hoary misconceptions concerning the age old topics of nature *v.* nurture and insight *v.* trial-and-error. The chapters on statistics and measurement are elementary but do show that it is not necessary to be mathematically sophisticated to be thoughtful. The discussion of scientific method is likely to disturb many dualists but none can deny that it is closely reasoned; the author has managed to combine the vigour of an iconoclast with the tact of an ambassador.

Bearing in mind the special needs of students in large classes the references are predominantly to standard readily accessible texts except where the relevant material can only be obtained from journals; since not everyone may appreciate his point of view a fair number of antidotes are included. The chapter summaries are so good that they may even defeat the author's own heuristic intentions.

To sum up we can say that this book is brief enough to be read as a whole, in no sense a student's mentor it provides an appetising *hors d'oeuvres* for the individual who wishes to press on and devour the whole of psychology, and finally it succeeds, with minor exceptions, in presenting a new subject to the beginner without insulting his intelligence.

ALAN COWEY.

Electronic Apparatus for Biological Research. By P. E. K. Donaldson. London. Butterworths Scientific Publications. 1958. Pp. xii + 718. 120s. (New York. Academic Press Inc. $20.00.)

The stated aim of this book is to provide both a textbook which begins with first principles and a work of reference; this aim has been achieved in very large measure. A biologist knowing some physics and no electronics need look no further for a sound introduction to electronic techniques.

Part I deals with principles and basic circuits, part II with components and construction. There is a chapter at the end of the book on transistors. Having absorbed these two parts the biologist may find it necessary to do some further reading on the subjects of filter theory, feedback and transistors.

Part III, on transducers, electrodes and indicators is a mine of information on the detection of energy in various forms, containing as it does the long experience of a number of well known biologists: the construction of micro-electrodes is fully described. But psychologists, who are attempting to automatize the control and recording of large scale experiments are less well served.

Part IV contains information on how to construct a number of widely used devices such as stimulators and biological amplifiers; circuit diagrams are given with component values.

Despite its high cost the book can be thoroughly recommended for departmental libraries where it will remain a valuable source of information for a long while.

A. M. UTTLEY.

Psychopathology: A Source Book. Edited by C. F. Reed, R. E. Alexander and S. S. Tomkins. Harvard University Press. 1958. Pp. 804 + xii. Price £5.

This source book consists of forty-six papers reprinted from scientific journals. The editors' aim in bringing together many varied and original contributions to abnormal psychology has been to provide a secondary text for courses in abnormal psychology and psychiatry. Each editor has taught the undergraduate course of normal psychology at Princeton: each felt the need for a single source of current periodical literature. In selecting their papers, the editors have not tried to cover their whole subject, but rather have tried to bring together half a dozen or so outstanding papers within five overlapping fields. These fields are: Psychopathology and early experience; Psychosomatic Disorders and Neurosis; Schizophrenic Psychoses; Somatic Factors in Psychopathology; Psychopathology and the social context. The papers range from a feuilleton on the social tensions which led to the expulsion for "Disloyalty" of 45 Faculty members from Berkeley University, to a detailed description of the errors in web-spinning made by spiders intoxicated with hallucinogenic drugs.

One of the most interesting facts about this volume is that it is a striking example of the insularity of American psychology. Forty-four of the forty-six papers were published in American journals, and only three of the contributions come from outside the North American hemisphere. These three are all from England, and the reviewer can only hope that American students will not think that these represent the best contributions made to these areas of Psychopathology by British clinics and medical schools during the last six years. On the other hand it is interesting to see what American psychologists themselves think to be their most significant contributions during this same period. In describing their criteria of selection the editors state that they chose papers firstly for their excellence, and secondly because of their novelty, promise or suggestiveness.

Sometimes these latter qualities seem to predominate, and it is fair to say that the scientific standard of the contributions is uneven and that some of the apparently well documented facts are very much under suspicion. It is thus a pity that there is no evaluation of any of the contributions though it must be admitted that this would have made the work even larger. These criticisms are minor ones and the reviewer readily confesses that he has thoroughly enjoyed reading many of the articles here brought together. Some of these he would, in the absence of the present work, almost certainly have never seen. One final comment, the price is high. Few English students will be able to afford this book, but it deserves a place in the library of any department in which psychopathology is taught.

ALICK ELITHORN.

The Measurement and Appraisal of Adult Intelligence. By David Wechsler. Fourth edition. Pp. ix + 297. London. Baillière, Tindall and Cox, Ltd. 1958. 40s. net.

Wechsler's Adult Intelligence Scale has found wide application in this country. Although no new principles underlie its construction, the Scale incorporates much that is best in the earlier intelligence tests and has the inestimable advantage of being fully standardized in relation to age. The principal changes in this edition are a new chapter on the factorial composition of the battery and a comparative analysis of the 1939 and 1955 standardizations. The sections dealing with the effects of brain damage and related clinical problems have been expanded and largely re-written. There is an extensive bibliography.

Although the theoretical assumptions governing this (as indeed every other) method of measuring intelligence have not been accepted by everyone, the usefulness of Wechsler's Scale as an empirical tool can hardly be challenged. In the clinical field, especially, it has fulfilled a very real need. One may therefore welcome warmly this new edition of an extremely useful text.

O. L. ZANGWILL.

Allgemeine Psychologie. By Th. Erismann. Sammlung Göschen Band 831. Berlin. Walter de Gruyter & Co. 1958. Pp. 146. DM. 2.40.

This scholarly little book provides a general introduction to psychology within the German philosophical tradition. It is concerned with such topics as the nature of sensation, the structure of perception and action, and the body-mind relation. Professor Erismann has also something to say about psychoanalysis and the relations of psychology to ethics and law. Unfortunately, his account does scant justice to modern experimental psychology or to lines of psychological interest current outside Germany. The reader must therefore be prepared for difficulties transcending those of the German language. None the less, this little book deserves attention as a brave and thoughtful restatement of some basic psychological issues.

O. L. ZANGWILL.

Psychologische Arbeiten. Schriftenreihe des Psychologischen Instuts der Johann-Wolfgang-Goethe-Universität zu Frankfurt am Main herausgegeben von Prof. Dr. Edwin Rausch.

1. Zur Problem der Sensumotorik. By Dr. Kurt Kohl. Pp. 110. 1956. DM 6.
2. Mengenvergleich und Übung. By Dr. Egon Becker. Pp. 63. 1957. DM 5.
3. Über die Rolle der Bezugsbereiche bei der Lokalisation. By Dr. Kurt Müller. Pp. 62. 1957. DM 5.
4. Instruktionsverständnis und Testleistung. By Dr. Manfred Sader. Pp. 111. 1957. DM 6.

This is a new series of monographs on experimental psychology from Professor Rausch's Laboratory at Frankfurt. Obviously based on doctoral dissertations, these studies deal with more or less conventional problems and relate in general to the pre-Hitlerian background of German experimental psychology. Dr. Kohl is concerned with motor skill and its sensory control, Dr. Becker with span of apprehension and some effects of practice, Dr. Müller with frames of reference in visual orientation, and Dr. Sander with the effect of the form of instructions upon mental test performance. All these studies were presumably adjudged worthy of the Ph.D. degree and of subsequent publication.

Although original and scholarly, one can detect in these studies little influence of the newer ideas current in Anglo-American psychology, more particularly information theory and its derivatives. There is also little sign of any radically new outlook—far rather a rediscovery of Gestalt theory and related approaches influential here twenty years ago. Yet one has the feeling that German psychology is once again on the move and may yet regain much of its traditional standing. These simple, yet thorough, experimental studies should certainly be read by specialists in their respective fields and may well stimulate useful inquiries. Professor Rausch has been fortunate in his research students and deserves commendation on his enterprise in securing publication of their work.

O. L. ZANGWILL.

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